Gravatt, Dan

From: Gravatt, Dan
Sent: Friday, August 23, 2013 12:47 PM
To: Barth, Edwin; Tolaymat, Thabet
Cc: Tapia, Cecilia; Hammerschmidt, Ron; Jackson, Robert W.; Weber, Robert
Subject: West Lake Landfill, FW: Plan review
Attachments: Charles O comment on Alternative LF covers WP.doc; FT Modeling SOW 4-22-2013.pdf; FT Modeling SOW 4-22-2013_stuart.docx; rrb Westlake work plans 12.19.12.docx; West Lake Landfill_72613.docx; Westlake SOW gw 5.14.13.docx; Work Plan - Alternative Cover Designs 2-3-13.pdf; Work Plan - Apatite Technology.pdf; Work Plan - Discount Rate.pdf; Work Plan - Partial Excavation 12-4-12.pdf; Work Plan- Alternative Area 2 RIM Volume.pdf; 20130509 WLL SFS Amendment work plans-MDNR comments.pdf

Ed, Thabet,

At Cecilia's request I am forwarding the six workplans for the Supplemental Supplemental Feasibility Study at West Lake Landfill and the comments the State of Missouri and EPA HQ have generated on those workplans.

Please review and provide your own comments on the SSFS workplans as you see fit. I am trying to organize a meeting in mid-to-late September (weeks of September 16th and 23rd) where the PRPs can ask questions and get clarification on EPA and State of Missouri comments on these workplans prior to revising the workplans and beginning the work. I'd like your comments before then so the PRPs can have a look at them prior to the meeting. Please let me know your availability to participate those weeks by conference line or in person.

The site-specific time charging code for this work is 2013 T 07WD 303DD2 0714BD01.

Sincerely,
Daniel R. Gravatt, PG
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Phone (913)-551-7324

Principles and integrity are expensive, but they are among the very few things worth having.

From: Tapia, Cecilia
Sent: Friday, August 23, 2013 11:45 AM
To: Gravatt, Dan
Cc: Weber, Robert; Hammerschmidt, Ron; Jackson, Robert W.
Subject: FW: Plan review

Dan, go ahead and send the workplans and all comments received so far to Dr. Barth. Also it looked like Thabet was interested so you can copy him.

Cecilia Tapia
Director, Superfund Division
U.S. Environmental Protection Agency - Region 7
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From: McKernan, John
Sent: Monday, August 19, 2013 1:21 PM
To: Tapia, Cecilia
Cc: Barth, Edwin
Subject: Plan review

Hi Cecilia-

Dr. Ed Barth indicated that he may be able to provide a review of the regrading/capping plan for the rad waste site we discussed. If possible, please have the RPM for the site send a hard-copy of the plan to Ed for his review.

I hope this is helpful.

Thank you,

John

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Subject: FW: West Lake Landfill, Fw: Alternative Landfill Covers Work Plan

Hi Doug, on this workplan, I had asked how you would like to proceed (see email below) – I went back and couldn't find a reply, so all I can offer at this point is that the Board's draft recommendation memos, as well as the technical consultation document signed in February of this year, all indicate:

The package presented to Board described an alternative as a hybrid cap/cover design incorporating both Resource Conservation and Recovery Act (RCRA) Subtitle D and Uranium Mill Tailings Radiation Control Act (UMTRCA) cover design features applied to an existing unlined landfill. However, the package lacked sufficient information on the long-term protectiveness of this alternative. Specifically, how the cap/cover remains protective given the increasing daughter ingrowth concentrations of radium 226/228, radon 222, and the increase in toxicity over time (1,000 years).

Both of these cover designs (RCRA Subtitle D and UMTRCA) have shortcomings for RIM waste itself, especially in a humid region. A comparison of various landfill capping designs addressing both humid region conditions and long-term protection from RIM (1,000 years) would be an important concept for the preferred remedy. However, the package did not appear to include alternative cap designs, i.e., EPA landfill cap guidance design, existing cap designs for similar RIM at Weldon Springs, or evapotranspiration cover cap system designs (OSWER Fact Sheets: EPA 542-F11-001, February 2011, Fact Sheet on Evapotranspiration Cover Systems for Waste Containment). For example, a RCRA Subtitle C/UMTRCA hybrid may be suitable for both long-term infiltration management and radiation shielding protection. The Board suggests that the Region include in its remedy selection process evaluations of cap designs similar to, but not limited to, the above conditions and guidances.

The alternative cover designs workplan addresses some of this, but not all of it (for example, the Board specifically mentioned Weldon Springs, the work plan does not).

Scope of Work and Schedule

Fate and Transport Modeling

Introduction

The U.S. EPA's October 12, 2012 letter (USEPA, 2012) requested that the Respondents perform fate and transport modeling at the West Lake Landfill (the Site). This Scope of Work (SOW) describes the modeling approach proposed to estimate potential fluxes of landfill leachate, possible radionuclide concentrations within the leachate, and the potential for transport of any radionuclide-contaminated leachate within the subsurface.

This SOW first outlines the objectives of the proposed modeling task. This is followed by a discussion of the general conceptual site model (CSM). Features of the Site that are expected to be simulated are described together with potential events and the physical and chemical transport processes that are envisioned as being incorporated in the modeling analyses. After describing the CSM and defining the objectives of the modeling calculations - which together define the necessary capabilities of the developed model – the calculation approach and the simulation programs proposed to meet the modeling objectives are identified. The final suite of scenarios to be simulated will be determined as part of the model implementation task.

It is assumed that modeling calculations will be performed on the basis of existing site-specific data, augmented where necessary with information and values obtained from technical literature and/or derived from professional experience.

Background

West Lake Landfill is located within the western portion of the St. Louis metropolitan area approximately two miles east of the Missouri River. Two areas of the Site contain radionuclides as a result of the use of soils mixed with leached barium sulfate residue as cover for municipal refuse. The Site is divided into two Operable Units (OUs). OU-1 consists of the two areas within the landfill where radionuclides are present and the area formerly described as the Ford Property, now called the Buffer Zone/Crossroad Property. OU-2 consists of other landfill areas that are not impacted by radionuclides (USEPA, 2008). Modeling calculations proposed in this SOW address the potential fate of radionuclides within OU-1. The nature and extent of radionuclides within OU-1 are discussed in the Remedial Investigation (EMSI, 2000) and a Supplemental Feasibility Study (SFS) (EMSI, 2011) for OU-1.

The selected remedy for OU-1 presented in the Record of Decision (ROD) includes source control through containment of waste materials and institutional controls for the landfilled waste materials (USEPA, 2008). Components of the ROD-selected remedy include the following:

1. A new landfill cover over the existing surface of Areas 1 and 2;
2. Consolidation of radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;
3. Groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;
4. Surface water runoff control;
5. Gas monitoring and control including radon and decomposition gas as necessary;
6. Institutional controls; and
7. Long-term surveillance and maintenance of the remedy.

Performance standards for these remedy components are detailed in the ROD. The following additional performance standards were also identified for the OU-1 remedy (EMSI, 2011):

- The proposed cap should meet the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions;
- Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations;
- Groundwater monitoring should be implemented at the waste management unit boundary and at off-site locations; and
- Flood control measures at the Site should meet or exceed design standards for a 500-year storm event under the assumption that the existing levee system is breached.

As defined in the OU-1 ROD, the new landfill cover for Areas 1 and 2 would consist of the following, from bottom to top: 2-ft of rock consisting of well-graded pit run rock and/or concrete/asphaltic rubble ranging from sand-sized up to 8-inches; 2-ft of compacted clay or silt that when compacted at optimum moisture content possesses a coefficient of permeability of 1×10^{-5} cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth. These layer thicknesses are based on requirements of the Missouri Solid Waste Rules and the description of the cover system in the ROD (USEPA, 2008). [A separate task will evaluate potential alternative landfill cover designs including possible use of an Evapotranspiration (ET) cover or incorporation of a geomembrane into the design of the ROD-selected landfill cover.]

Modeling Objectives

The proposed fate-and-transport modeling will provide site-specific calculations of the potential for radionuclides to leach from the landfill, reach the underlying saturated aquifer, and result in unacceptable concentrations within groundwater or surface water downgradient of the landfill. The following modeling objectives are proposed:

1. Calculate the potential for migration of leachate containing radionuclides from waste materials:
    a. Under current conditions, to validate the modeling approach and potentially bound parameter values for later predictive analyses;

b. Under future conditions, assuming the emplacement of a new landfill cover for OU-1; and
c. Under future conditions, following the period of active maintenance of the new landfill cover for OU-1.

2. Calculate the potential for leachate containing radionuclides to migrate vertically through waste that is uncontaminated by radiological constituents and through native materials beneath the landfill, and to impact underlying groundwater;

If the prior calculations indicate that a potentially measurable impact to groundwater may occur:

3. Calculate the likely fate of any radionuclides that reach groundwater, and the potential for the development of a contaminant plume;
4. Calculate concentrations over time of radionuclides in groundwater at defined locations including, but not limited to, the property fence line/boundary; and
5. Evaluate the potential for radionuclides that reach the groundwater to migrate toward, and discharge to, the Missouri River at levels exceeding standards.

These are the specific objectives of the proposed modeling task. The model may, at some later time, be used to support other Site objectives such as (a) designing a suitable groundwater monitoring program, including defining the locations and frequency of sampling to detect any potential off-site migration of radionuclide constituents and/or (b) evaluating alternative landfill cover designs such as an ET cover or incorporation of a geomembrane.

Fate and Transport Conceptual Site Model

Because the overall mass of radium at the Site is small[1] and future infiltration through the landfill materials will be less than at present due to the planned emplacement of an additional landfill cover over the existing landfill cover material, it might be expected that concentrations of radium will necessarily decline in the future. However, site-specific conditions need to be evaluated before reaching this conclusion. For example, uranium and thorium that are present in the waste materials will continue to decay, and in doing so, generate radium. In addition, the landfill and groundwater geochemistry will change over time due to the eventual exhaustion of readily-biodegradable organic matter in the landfill. This will in turn affect the stability of some minerals available to sequester radium.

Selection of an appropriate calculation method, and of a suitable simulation code or suite of codes to implement the calculations, requires that the modeling requirements are defined. In the context of radionuclides, the Nuclear Energy Agency Organization for Economic Co-operation and Development (NEA-OECD, 2000) developed a systematic approach to define relevant scenarios for safety assessment studies at radioactive waste management sites. This consists of identifying and prioritizing the Features,

[1] Using the arithmetic mean concentrations (reported as pCi/gram) from Appendix A of the RI, as well as an estimated mass of soils for the Area 1 and 2 surface and subsurface zones at the West Lake site, a preliminary estimate of the amount of ^{226}Ra at the site indicates that there is less than 40 grams of ^{226}Ra within Areas 1 and 2.

Events, and Processes (*FEPs*[2]) that potentially affect the fate and transport of radionuclides at a site, and developing and modeling individual scenarios, each of which consists of a well-defined, connected sequence of selected FEPs. This SOW identifies principal FEPs for the Site that it is anticipated will require consideration in the modeling analyses. However, the final site-specific FEPs and the suite of simulation scenarios will be defined during the implementation phase of the modeling task.

<u>Primary Site-Specific Features</u>

An overview of the primary features that affect radionuclide fate and transport is provided here. The source of radionuclides of potential concern is leached barium sulfate residue mixed with soil and used as daily and intermediate cover for municipal solid waste deposited in landfill Areas 1 and 2. This radiologically-impacted material (RIM) is currently covered by old landfill cover material. Underlying the RIM is refuse that does not contain radionuclides, and under that is partially saturated alluvium. Over time some fraction of radionuclide-bearing water could potentially percolate vertically to reach the water table. According to the RI [EMSI, 2000], the saturated aquifer largely consists of alluvial sand, underlain by more impervious limestone and dolomite bedrock. The horizontal hydraulic gradient within the aquifer is relatively flat, which would tend to result in slow advection along a trajectory that intersects the Missouri River downgradient of the Site. If radionuclide-containing water currently located within or under OU-1 were to reach the water table beneath the landfill, then mixing, dispersion, and dilution of that radionuclide-containing water would occur at the water table beneath the landfill, within the saturated aquifer, and within the hyporheic zone of the Missouri River.

A dominant feature [which, depending upon the simulation scenario, may also constitute an event] that must be considered in the modeling calculations, and for which a design is presented in the ROD but for which potential alternatives have since been identified by USEPA for evaluation, is the new landfill cover to be installed over the current surface of the old landfill cover. Modeling calculations proposed under this SOW will only consider the ROD-selected landfill cover, the design of which is detailed above and within the ROD (USEPA, 2008). However, the developed model could be used at some later time to evaluate alternative cover designs such as an ET cap and/or the incorporation of a geomembrane within the ROD-selected landfill cover.

<u>Primary Site-Specific Events</u>

Several events may affect the landfill water balance, the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example events are summarized in Table 1.

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[2] The following definitions apply (Sandia National Laboratories, 2010):

Feature – An object, structure, or condition that has a potential to affect repository system performance.

Event – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during an interval that is short compared to the period of performance.

Process – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during all or a significant part of the period of performance.

Table 1 Primary Events and Processes of Potential Radionuclide Fate and Transport at the Site.

FEP Element	Description
Events:	1. Transition from current cover conditions to final cover under active maintenance: • Cover design (*2-ft of well-graded pit run rock and/or concrete/asphaltic rubble; 2-ft of compacted clay or silt with a coefficient of permeability of 1 x 10^{-5} cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth*) • Period of active maintenance (*30 yr min/200 yr ROD/1000 yr UMTRA-compliant*) 2. Transition from active maintenance period to post-active maintenance period: • Intermediate infiltration rates (*reduced by grade, vegetation, etc.*) 3. [Bio-]degradation of landfill wastes: • Degradation time-frame (*rapid versus extended time*) • Effects and duration on chemistry (*oxidation-reduction [redox], carbonate, CO2, pH, etc.*) 4. Flood events: • 500 year
Processes:	1. Net infiltration: • Under current conditions • During period of active cover maintenance (*incorporating ET as a process*) • Following period of active cover maintenance (*reduced by grade, vegetation, etc.*) 2. Ingrowth of radium from uranium and thorium decay: 3. Partitioning of radium, uranium, thorium from soil to water/landfill leachate: • Decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 4. Transport within the partially-saturated zone: 5. Mixing at the water table: • Depth of penetration, and dilution • Sorption/complexation, mineral dissolution/precipitation 6. Transport within the saturated aquifer: • Advection, dispersion, decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 7. Discharge to, and mixing with, Missouri River: • Hyporheic zone chemical process • Sorption/complexation, mineral dissolution/precipitation

The Uranium Mill Tailings Remediation Program (UMTRA) focused on the design of purpose-built repositories for uranium tailings piles; however, the UMTRA containment design time-frame of 1000 years is a guide for other radionuclide wastes.

One important event is the grading of Areas 1 and 2 and the emplacement of the final landfill cover on top of the current landfill cover material in these areas. This new cover will greatly reduce infiltration and the potential for mass transfer of radionuclides to mobile water for the period of active maintenance. If active maintenance were to cease, over some time the effectiveness of the landfill cover may decline, potentially resulting in an increased infiltration rate. However, infiltration rates following cessation of active cover maintenance would be expected to be lower than under current conditions since the cover design incorporates a grade (whereas, the majority of the current landfill cover is flat) and other features that would endure for many years following cessation of active maintenance.

Another important event is the slowing rate of biodegradation of organic materials in the landfill over time; this will alter the geochemistry within the landfill wastes and impact radionuclide partitioning between mobile and immobile phases in the refuse that contains RIM, the underlying refuse that does not contain RIM, and potentially the underlying alluvial aquifer.

Primary Site-Specific Processes

Several processes may affect the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example processes are summarized in Table 1. One important process is the complex interaction of the RIM with the surrounding pore water, and the role of pore water and soil chemistry on the potential for radionuclide partitioning and migration. Since radionuclide geochemistry will be an important process in the modeling scenarios, an overview of relevant radionuclide geochemistry is provided below.

Geochemistry of Radionuclide Decay, Ingrowth, Partitioning and Migration

Radium Geochemistry

Radium dominantly occurs within leached barium sulfate residues that were mixed with soil and used as daily and intermediate soil cover for solid waste disposed at Areas 1 and 2. The co-precipitation of radium into barium sulfate is a well known process to control radium (Doerner and Hoskins, 1925; Bruno et al., 2007; Zhu 2004a, 2004b; Mahoney 1998, 2001; Grandia et al., 2008; Bosbach et al., 2010). Consequently, equilibrium between pore water and the radium component of barium sulfate will define the initial radium source term leached from the RIM.

Radium may also be attenuated in clean alluvium and groundwater via adsorption onto iron-bearing minerals, ion exchange on clays, and co-precipitation with other sulfate and carbonate minerals such as gypsum and calcite. Of these mechanisms, co-precipitation is expected to be the dominant process close to the landfill due to the sandy nature of the aquifer and expectedly low redox conditions (making iron oxyhydroxides unstable). Downgradient of the landfill - and increasingly within the landfill over time - more oxidizing conditions may be present, and the abundance of iron-bearing minerals available for radium adsorption may increase. Another important consequence of the change in landfill biogeochemistry over time is the likely increase in pH as readily-biodegradable material is consumed. As pH increases, the amount of calcite that will precipitate will increase, and radium co-precipitation with calcite will be more favored, reducing its mobility.

Uranium Geochemistry

Uranium and thorium are important because they occur within the RIM and they decay over time, producing additional radium. Under current conditions uranium concentrations are expected to be controlled by uraninite (UO_2) due to the reducing conditions within the landfill. If oxidizing conditions return, however, then uranium solubility could be controlled by the generally more soluble U^{+6} (uranyl) minerals such as schoepite $[UO_2(OH)_2 \cdot 2H_2O]$ or less soluble forms such as carnotite (KUO_2VO_4) and tyuyamunite $[Ca(UO_2)_2(VO_4)_2]$ (Tokunaga et al., 2009). In addition to the oxidation state of uranium, other factors affecting dissolved concentrations include levels of dissolved carbonate generated by biodegradation (which increase solubility) and presence of iron oxyhydroxides (which decrease solubility).

Thorium Geochemistry

Thorium is not redox sensitive and solubility conditions will be controlled by thorianite (ThO_2) under all redox conditions. Complexation reactions that form thorium carbonate complexes are not as significant as those for uranyl carbonate complexes, but they will play a role in thorianite solubility calculations. Reductions in carbon dioxide pressures will also reduce thorium concentrations in groundwater.

The long-term in-growth of ^{226}Ra from ^{230}Th is complicated by the fact that the majority of in-growth radium will be retained within the crystal structure of the thorianite (ThO_2). Only a small fraction of the radium that is produced from the decay of thorium will have the potential to be released to groundwater. This fraction is expected to be derived from near the surface of the thorianite crystals.

Calculation Approach

General

The approach to undertaking modeling calculations will follow the sequence of steps defined below:

- Determine and document final FEPs;
- Identify simulation scenarios, based on the final FEPs;
- Identify parameter ranges and uncertainties;
- Develop necessary model(s);
- Complete model calculations; and
- Present and interpret results.

As the modeling is implemented, there will be some iteration between steps in the sequence. It is expected that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. It is envisioned that communication and interaction will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables for review and discussion.

Graded Approach

A graded approach is proposed to undertake the modeling analyses (USEPA 2002, 2009). This graded approach will:

- Use relatively simple methods for initial calculations under the premise that the inherent conservatisms are protective of groundwater and other receptors. Increasing simulation rigor will only be used, if necessary, if simpler approach(es) yield unreasonable results.
- Provide a mechanism to cease model calculations if it becomes evident that no further calculations are necessary. For example, saturated zone flow and transport calculations will only be undertaken if geochemical and vadose zone modeling calculations suggest that a potentially measurable impact to groundwater could occur.

The modeling approach and specific model calculations will be designed to incorporate the principal FEPs while mitigating the potential for computationally-intensive calculations that prevent a thorough exploration of parameter variability and scenario uncertainty. Multiple scenarios will be simulated to evaluate the potential impact of scenario uncertainty on model outcomes, while sensitivity analysis will be used to evaluate the potential impact of parameter variability on model outcomes.

Modeling analyses will be designed to predict the concentration of radium in groundwater for a period of 1,000 years. Concentrations will be forecast at defined compliance locations including, but not limited to, the property fence line/boundary, for the 1,000-year period and will be compared to regulatory standards. If regulatory standards are not exceeded then no further analyses will be required. However, if simulated concentrations exceed regulatory standards, the graded approach will be used to identify the technical element of the modeling approach that incurs the most inherent conservatism in the calculations so that element of the modeling approach can be treated more rigorously to reduce that inherent conservatism (Dixon et al, 2008). If the graded simulation approach has been applied until all inherent conservatisms have been reduced or eliminated, yet simulated concentrations exceed regulatory standards, then this will be considered to be a reliable result.

Simulation Code Selection

Table 1 outlines primary events and processes that will be considered in the calculations. The range of potential outcomes will be evaluated by performing several model simulations that consider reasonable alternate conceptualizations of subsurface conditions. Since parameterization of the geochemical component of the model is likely subject to more variability and uncertainty than the groundwater flow component of the model - given the large number of chemical processes that potentially affect radium fate and transport – advective-dispersive migration will be simulated as one-dimensional (1-D), coupled with a rigorous treatment of the complex geochemical processes. The following sequential series of calculations is proposed to collectively comprise the model [consistent with the graded approach, some calculations will only be undertaken if necessary based on the results of preceding calculations]:

1. The Hydrologic Evaluation of Landfill Performance (HELP) code will be used to determine the run-off component of the surface-water balance and remaining water available for infiltration through cover materials under current conditions, final cover conditions, and following the period of active cover maintenance;
2. HYDRUS 1-D (Simunek et al., 1998) will be used to simulate the water balance in the subsurface (after run-off has been accounted for) and the migration of infiltrating water;
3. The USGS-supported geochemical simulation software, PHREEQC (Parkhurst and Appelo, 1999), which is linked to HYDRUS through the HP1 program (Jacques and Simunek, 2005), will be executed simultaneously to provide concentrations of radionuclides in the leachate as it moves within the unsaturated refuse and underlying unsaturated alluvium;
4. The depth of penetration of any leachate that reaches the water table will be calculated using an established method such as that detailed by USEPA (1996);
5. PHREEQC, linked with HYDRUS, will then be used to calculate the effects of mixing on geochemistry that occurs between the leachate and groundwater at the water table;
6. Output from these calculations will provide the time-varying groundwater composition for simulating 1-D radionuclide fate and transport within the saturated zone toward the Missouri River using PHREEQC; and
7. PHREEQC will be used to represent geochemical processes that may occur within the hyporheic zone of the Missouri River.

<u>Overview of HELP Calculations</u>

HELP (Schroeder, P.R. et al, 1994a, 1994b; Berger, 2011; Berger and Schroeder, 2012) is a program originally developed by USEPA to evaluate the effectiveness of landfill cover designs. HELP will first be used to estimate the typical, quasi-steady-state surface-water balance, emphasizing the run-off rate and the net water available for infiltration through the current landfill cover. The purpose of these calculations is solely to support validation of the modeling approach and constrain the values of certain parameters to be consistent with historical water samples. HELP will then be used to make similar calculations to estimate run-off and the net water available for infiltration through the new landfill cover that would be constructed under the ROD-selected remedy, and to estimate run-off and the net water available for infiltration through the new cover following the period of active maintenance. Alternate periods of active maintenance may be considered in alternate simulation scenarios. The HELP model can explicitly account for rainfall-runoff under alternate cover designs, including alternate slopes (grades).

<u>Overview of HYDRUS 1-D Calculations</u>

HYDRUS-1D (Simunek et al., 1998) is a public domain Windows-based modeling environment that simulates the movement of water, heat, and multiple solutes in variably saturated media. The flow equation formulation in HYDRUS incorporates a sink term to account for water uptake by plant roots, as well as a dual-porosity type flow capability in which one fraction of the water content is mobile and another fraction is immobile. The solute transport equations consider advective-dispersive transport in the liquid phase, as well as diffusion in the gaseous phase. HYDRUS 1-D (Simunek et al., 1998) will be

used to simulate the water balance in the subsurface (after run-off has been accounted for), and the migration of infiltrating water.

HYDRUS 1-D is linked to PHREEQC through the HP1 modeling software (Jacques and Simunek, 2005). This allows simulation of complex bio-geochemical reactions. Consistent with the graded modeling approach, the initial simulations will assume that radionuclide attenuation in landfill leachate only occurs in groundwater. However, the HP1 software may be used to estimate attenuation in the non-radiologically impacted refuse and unsaturated alluvium underlying Areas 1 and 2 if unreasonable results are obtained using the more conservative simplifying assumption.

Overview of PHREEQC Calculations

Geochemical modeling will first be completed to estimate the leaching potential of various radionuclides under current site conditions. The purpose of these calculations is to support validation of the groundwater modeling approach and constrain the values of certain parameters to be consistent with historical water samples. Following these calculations, the modeling will be used to evaluate the leaching potential under long-term future conditions under the ROD-selected remedy.

Geochemical modeling methods to estimate source term concentrations for the radio-isotopes will primarily rely upon equilibrium thermodynamics and will be based upon mineral solubility relationships using current ground water compositions. Calculations will be performed using PHREEQC (Parkhurst and Apello, 1999). Solubility calculations for end member phases will be used for thorium and uranium. Radium will be assumed to be present as a solid-solution in barite with a lower thermodynamic activity. Solubility constants for uranium and thorium will, for the most part, be based upon the OECD NEA compilations (Guillaumont et al., 2003; and Rand et al., 2008). Other data sources will be used as needed (Dong and Brooks, 2006, 2008; Duro et al., 2006; Langmuir, 1978; Tokunaga et al., 2009). The ingrowth of ^{226}Ra from ^{230}Th is a time dependent process and the kinetics capabilities in PHREEQC will be used to estimate the production of ^{226}Ra for a period of 1,000 years.

1-D transport modeling will also be performed with PHREEQC. Modeling will simulate a chemical system that is sufficiently complex to include the effects of landfill and groundwater geochemistry described above. Site-specific groundwater and soil data for uranium, thorium, and radium will define initial concentrations for these isotopes. The site analytical results, particularly the groundwater analyses, will also provide details on the overall geochemical environment of the landfill. The PHREEQC fate and transport model will include the following features:

- The effect of radium in-growth from the decay of thorium over time;
- Decreased methane generation and a possible change in site redox conditions from the reducing conditions currently present at the site to more oxidizing conditions;
- Radionuclide precipitation and/or co-precipitation, such as the partitioning of radium into calcite (Yoshida et al., 2008) present within the landfill;
- Changes in iron stability and potential precipitation of iron-bearing phases for the adsorption of radionuclides; and

- Adsorption reactions (surface complexation and ion exchange) (Dzombak and Morel, 1990; Mahoney et al. 2009a, b; Rojo, et al., 2008; Pabalan et al., 1998).

<u>Model Validation and Predictive Sensitivity Analysis</u>

Historical groundwater data have exhibited few detections of radionuclides. As such, a rigorous calibration exercise is not warranted or justifiable. However, the historical data will be used to validate the modeling calculations and potentially bound the values of some parameter combinations by simulating current conditions prior to undertaking predictive calculations. Multiple simulations will be conducted to evaluate the range of forecasts of possible impacts on groundwater beneath the landfill, at the property fence line/boundary, within surface water, at any defined receptors, and at any other locations of interest. Multiple scenarios will be simulated and predictive sensitivity analyses will be used to evaluate the potential impact of parameter variability on model outcomes at these locations. Although outside the scope of the proposed modeling task, the results of multiple-scenario and parameter-/prediction-sensitivity analyses can help guide the sampling frequency for long-term monitoring programs by providing a range of possible arrival-times and peak-concentrations for contamination at identified compliance locations such as the property fence line/boundary.

Deliverables

The final deliverable anticipated to be developed from the modeling effort is a Technical Memorandum documenting the technical approach, assumptions, model development, parameterization, simulated scenarios, and results obtained. However, it is anticipated that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. Communication and interaction with USEPA will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables to USEPA for review and discussion.

No revisions to the SFS report are expected to be required as a result of this modeling effort.

Schedule

It is anticipated that the geochemical evaluation of potential leaching of radionuclides, including preparation and submittal of the Technical Memorandum, will be completed within twelve weeks of the approval to proceed.

References

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Scope of Work and Schedule

Fate and Transport Modeling

Introduction

The U.S. EPA's October 12, 2012 letter (USEPA, 2012) requested that the Respondents perform fate and transport modeling at the West Lake Landfill (the Site). This Scope of Work (SOW) describes the modeling approach proposed to estimate potential fluxes of landfill leachate, possible radionuclide concentrations within the leachate, and the potential for transport of any radionuclide-contaminated leachate within the subsurface.

This SOW first outlines the objectives of the proposed modeling task. This is followed by a discussion of the general conceptual site model (CSM). Features of the Site that are expected to be simulated are described together with potential events and the physical and chemical transport processes that are envisioned as being incorporated in the modeling analyses. After describing the CSM and defining the objectives of the modeling calculations - which together define the necessary capabilities of the developed model – the calculation approach and the simulation programs proposed to meet the modeling objectives are identified. The final suite of scenarios to be simulated will be determined as part of the model implementation task.

It is assumed that modeling calculations will be performed on the basis of existing site-specific data, augmented where necessary with information and values obtained from technical literature and/or derived from professional experience.

Background

West Lake Landfill is located within the western portion of the St. Louis metropolitan area approximately two miles east of the Missouri River. Two areas of the Site contain radionuclides as a result of the use of soils mixed with leached barium sulfate residue as cover for municipal refuse. The Site is divided into two Operable Units (OUs). OU-1 consists of the two areas within the landfill where radionuclides are present and the area formerly described as the Ford Property, now called the Buffer Zone/Crossroad Property. OU-2 consists of other landfill areas that are not impacted by radionuclides (USEPA, 2008). Modeling calculations proposed in this SOW address the potential fate of radionuclides within OU-1. The nature and extent of radionuclides within OU-1 are discussed in the Remedial Investigation (EMSI, 2000) and a Supplemental Feasibility Study (SFS) (EMSI, 2011) for OU-1.

The selected remedy for OU-1 presented in the Record of Decision (ROD) includes source control through containment of waste materials and institutional controls for the landfilled waste materials (USEPA, 2008). Components of the ROD-selected remedy include the following:

1. A new landfill cover over the existing surface of Areas 1 and 2;
2. Consolidation of radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;
3. Groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;
4. Surface water runoff control;
5. Gas monitoring and control including radon and decomposition gas as necessary;
6. Institutional controls; and
7. Long-term surveillance and maintenance of the remedy.

Performance standards for these remedy components are detailed in the ROD. The following additional performance standards were also identified for the OU-1 remedy (EMSI, 2011):

- The proposed cap should meet the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions;
- Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations;
- Groundwater monitoring should be implemented at the waste management unit boundary and at off-site locations; and
- Flood control measures at the Site should meet or exceed design standards for a 500-year storm event under the assumption that the existing levee system is breached.

As defined in the OU-1 ROD, the new landfill cover for Areas 1 and 2 would consist of the following, from bottom to top: 2-ft of rock consisting of well-graded pit run rock and/or concrete/asphaltic rubble ranging from sand-sized up to 8-inches; 2-ft of compacted clay or silt that when compacted at optimum moisture content possesses a coefficient of permeability of 1×10^{-5} cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth. These layer thicknesses are based on requirements of the Missouri Solid Waste Rules and the description of the cover system in the ROD (USEPA, 2008). [A separate task will evaluate potential alternative landfill cover designs including possible use of an Evapotranspiration (ET) cover or incorporation of a geomembrane into the design of the ROD-selected landfill cover.]

Modeling Objectives

The proposed fate-and-transport modeling will provide site-specific calculations of the potential for radionuclides to leach from the landfill, reach the underlying saturated aquifer, and result in unacceptable concentrations within groundwater or surface water downgradient of the landfill. The following modeling objectives are proposed:

1. Calculate the potential for migration of leachate containing radionuclides from waste materials:
    a. Under current conditions, to validate the modeling approach and potentially bound parameter values for later predictive analyses;

Commented [E1]: Should note that at Superfund sites models are usually used to just predict potential flow of the plume to decide where to put the monitoring wells

b. Under future conditions, assuming the emplacement of a new landfill cover for OU-1; and
c. Under future conditions, following the period of active maintenance of the new landfill cover for OU-1.

2. Calculate the potential for leachate containing radionuclides to migrate vertically through waste that is uncontaminated by radiological constituents and through native materials beneath the landfill, and to impact underlying groundwater;

If the prior calculations indicate that a potentially measurable impact to groundwater may occur:

3. Calculate the likely fate of any radionuclides that reach groundwater, and the potential for the development of a contaminant plume;
4. Calculate concentrations over time of radionuclides in groundwater at defined locations including, but not limited to, the edge of the waste management unit ~~property fence line/~~boundary; and
5. Evaluate the potential for radionuclides that reach the groundwater to migrate toward, and discharge to, the Missouri River at levels exceeding standards.

Commented [E2]: For Superfund sites, the point of compliance is throughout the plume, except under waste management units.

These are the specific objectives of the proposed modeling task. The model may, at some later time, be used to support other Site objectives such as (a) designing a suitable groundwater monitoring program, including defining the locations and frequency of sampling to detect any potential off-site migration of radionuclide constituents and/or (b) evaluating alternative landfill cover designs such as an ET cover or incorporation of a geomembrane.

Fate and Transport Conceptual Site Model

~~Because the overall mass of radium at the Site is small[1] and future infiltration through the landfill materials will be less than at present due to the planned emplacement of an additional landfill cover over the existing landfill cover material, it might be expected that concentrations of radium will necessarily decline in the future. However, site-specific conditions need to be evaluated before reaching this conclusion. For example, u~~Uranium and thorium that are present in the waste materials will continue to decay, and in doing so, generate radium. In addition, the landfill and groundwater geochemistry will change over time due to the eventual exhaustion of readily-biodegradable organic matter in the landfill. This will in turn affect the stability of some minerals available to sequester radium.

Commented [E3]: Radium mass is always low compared to chemical contaminants even if it poses the same level of potential cancer risk.

Commented [E4]: Why would you expect this since concentrations of radium will increase 35 fold due to ingrowth of radium.

Selection of an appropriate calculation method, and of a suitable simulation code or suite of codes to implement the calculations, requires that the modeling requirements are defined. In the context of radionuclides, the Nuclear Energy Agency Organization for Economic Co-operation and Development (NEA-OECD, 2000) developed a systematic approach to define relevant scenarios for safety assessment studies at radioactive waste management sites. This consists of identifying and prioritizing the Features,

Commented [E5]: Why would an OECD guidance be relevant? They use a completely different risk management framework in the OECD countries, similar to the NRC regulations (25 mrem/yr, no separate groundwater standards based on MCLs) that EPA has determined are not protective under CERCLA

[1] Using the arithmetic mean concentrations (reported as pCi/gram) from Appendix A of the RI, as well as an estimated mass of soils for the Area 1 and 2 surface and subsurface zones at the West Lake site, a preliminary estimate of the amount of ^{226}Ra at the site indicates that there is less than 40 grams of ^{226}Ra

within Areas 1 and 2.

Events, and Processes (*FEPs*[2]) that potentially affect the fate and transport of radionuclides at a site, and developing and modeling individual scenarios, each of which consists of a well-defined, connected sequence of selected FEPs. This SOW identifies principal FEPs for the Site that it is anticipated will require consideration in the modeling analyses. However, the final site-specific FEPs and the suite of simulation scenarios will be defined during the implementation phase of the modeling task.

Primary Site-Specific Features

An overview of the primary features that affect radionuclide fate and transport is provided here. The source of radionuclides of potential concern is leached barium sulfate residue mixed with soil and used as daily and intermediate cover for municipal solid waste deposited in landfill Areas 1 and 2. This radiologically-impacted material (RIM) is currently covered by old landfill cover material. Underlying the RIM is refuse that does not contain radionuclides, and under that is partially saturated alluvium. Over time some fraction of radionuclide-bearing water could potentially percolate vertically to reach the water table. According to the RI [EMSI, 2000], the saturated aquifer largely consists of alluvial sand, underlain by more impervious limestone and dolomite bedrock. The horizontal hydraulic gradient within the aquifer is relatively flat, which would tend to result in slow advection along a trajectory that intersects the Missouri River downgradient of the Site. If radionuclide-containing water currently located within or under OU-1 were to reach the water table beneath the landfill, then mixing, dispersion, and dilution of that radionuclide-containing water would occur at the water table beneath the landfill, within the saturated aquifer, and within the hyporheic zone of the Missouri River.

A dominant feature [which, depending upon the simulation scenario, may also constitute an event] that must be considered in the modeling calculations, and for which a design is presented in the ROD but for which potential alternatives have since been identified by USEPA for evaluation, is the new landfill cover to be installed over the current surface of the old landfill cover. Modeling calculations proposed under this SOW will only consider the ROD-selected landfill cover, the design of which is detailed above and within the ROD (USEPA, 2008). However, the developed model could be used at some later time to evaluate alternative cover designs such as an ET cap and/or the incorporation of a geomembrane within the ROD-selected landfill cover.

Primary Site-Specific Events

Several events may affect the landfill water balance, the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example events are summarized in Table 1.

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[2] The following definitions apply (Sandia National Laboratories, 2010):

Feature – An object, structure, or condition that has a potential to affect repository system performance.

Event – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during an interval that is short compared to the period of performance.

Process – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during all or a significant part of the period of performance.

Table 1 Primary Events and Processes of Potential Radionuclide Fate and Transport at the Site.

FEP Element	Description
Events:	1. Transition from current cover conditions to final cover under active maintenance: • Cover design (*2-ft of well-graded pit run rock and/or concrete/asphaltic rubble; 2-ft of compacted clay or silt with a coefficient of permeability of 1×10^{-5} cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth*) • Period of active maintenance (*30 yr min/200 yr ROD/1000 yr UMTRA-compliant*) 2. Transition from active maintenance period to post-active maintenance period: • Intermediate infiltration rates (*reduced by grade, vegetation, etc.*) 3. [Bio-]degradation of landfill wastes: • Degradation time-frame (*rapid versus extended time*) • Effects and duration on chemistry (*oxidation-reduction [redox], carbonate, CO2, pH, etc.*) 4. Flood events: • 500 year
Processes:	1. Net infiltration: • Under current conditions • During period of active cover maintenance (*incorporating ET as a process*) • Following period of active cover maintenance (*reduced by grade, vegetation, etc.*) 2. Ingrowth of radium from uranium and thorium decay: 3. Partitioning of radium, uranium, thorium from soil to water/landfill leachate: • Decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 4. Transport within the partially-saturated zone: 5. Mixing at the water table: • Depth of penetration, and dilution • Sorption/complexation, mineral dissolution/precipitation 6. Transport within the saturated aquifer: • Advection, dispersion, decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 7. Discharge to, and mixing with, Missouri River: • Hyporheic zone chemical process • Sorption/complexation, mineral dissolution/precipitation

The Uranium Mill Tailings Remediation Program (UMTRA) focused on the design of purpose-built repositories for uranium tailings piles; however, the UMTRA containment design time-frame of 1000 years is a guide for other radionuclide wastes.

One important event is the grading of Areas 1 and 2 and the emplacement of the final landfill cover on top of the current landfill cover material in these areas. This new cover will greatly reduce infiltration and the potential for mass transfer of radionuclides to mobile water for the period of active maintenance. If active maintenance were to cease, over some time the effectiveness of the landfill cover may decline, potentially resulting in an increased infiltration rate. However, infiltration rates following cessation of active cover maintenance would be expected to be lower than under current conditions since the cover design incorporates a grade (whereas, the majority of the current landfill cover is flat) and other features that would endure for many years following cessation of active maintenance. It should be noted that CERCLA requires 5-year reviews of any site not able to be used for unrestricted use, so this assumption of cessation of active controls is a hypothetical situation.

Another important event is the slowing rate of biodegradation of organic materials in the landfill over time; this will alter the geochemistry within the landfill wastes and impact radionuclide partitioning between mobile and immobile phases in the refuse that contains RIM, the underlying refuse that does not contain RIM, and potentially the underlying alluvial aquifer.

Primary Site-Specific Processes

Several processes may affect the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example processes are summarized in Table 1. One important process is the complex interaction of the RIM with the surrounding pore water, and the role of pore water and soil chemistry on the potential for radionuclide partitioning and migration. Since radionuclide geochemistry will be an important process in the modeling scenarios, an overview of relevant radionuclide geochemistry is provided below.

Geochemistry of Radionuclide Decay, Ingrowth, Partitioning and Migration

Radium Geochemistry

Radium dominantly occurs within leached barium sulfate residues that were mixed with soil and used as daily and intermediate soil cover for solid waste disposed at Areas 1 and 2. The co-precipitation of radium into barium sulfate is a well known process to control radium (Doerner and Hoskins, 1925; Bruno et al., 2007; Zhu 2004a, 2004b; Mahoney 1998, 2001; Grandia et al., 2008; Bosbach et al., 2010). Consequently, equilibrium between pore water and the radium component of barium sulfate will define the initial radium source term leached from the RIM.

Radium may also be attenuated in clean alluvium and groundwater via adsorption onto iron-bearing minerals, ion exchange on clays, and co-precipitation with other sulfate and carbonate minerals such as gypsum and calcite. Of these mechanisms, co-precipitation is expected to be the dominant process close to the landfill due to the sandy nature of the aquifer and expectedly low redox conditions (making iron oxyhydroxides unstable). Downgradient of the landfill - and increasingly within the landfill over time - more oxidizing conditions may be present, and the abundance of iron-bearing minerals available for radium adsorption may increase. Another important consequence of the change in landfill biogeochemistry over time is the likely increase in pH as readily-biodegradable material is consumed. As pH increases, the amount of calcite that will precipitate will increase, and radium co-precipitation with calcite will be more favored, reducing its mobility.

Uranium Geochemistry

Uranium and thorium are important because they occur within the RIM and they decay over time, producing additional radium. Under current conditions uranium concentrations are expected to be controlled by uraninite (UO_2) due to the reducing conditions within the landfill. If oxidizing conditions return, however, then uranium solubility could be controlled by the generally more soluble U^{+6} (uranyl) minerals such as schoepite $[UO_2(OH)_2 \cdot 2H_2O]$ or less soluble forms such as carnotite (KUO_2VO_4) and tyuyamunite $[Ca(UO_2)_2(VO_4)_2]$ (Tokunaga et al., 2009). In addition to the oxidation state of uranium, other factors affecting dissolved concentrations include levels of dissolved carbonate generated by biodegradation (which increase solubility) and presence of iron oxyhydroxides (which decrease solubility).

Thorium Geochemistry

Thorium is not redox sensitive and solubility conditions will be controlled by thorianite (ThO_2) under all redox conditions. Complexation reactions that form thorium carbonate complexes are not as significant as those for uranyl carbonate complexes, but they will play a role in thorianite solubility calculations. Reductions in carbon dioxide pressures will also reduce thorium concentrations in groundwater.

The long-term in-growth of ^{226}Ra from ^{230}Th is complicated by the fact that the majority of in-growth radium will be retained within the crystal structure of the thorianite (ThO_2). Only a small fraction of the radium that is produced from the decay of thorium will have the potential to be released to groundwater. This fraction is expected to be derived from near the surface of the thorianite crystals.

Calculation Approach

General

The approach to undertaking modeling calculations will follow the sequence of steps defined below:

- Determine and document final FEPs;
- Identify simulation scenarios, based on the final FEPs;
- Identify parameter ranges and uncertainties;
- Develop necessary model(s);
- Complete model calculations; and
- Present and interpret results.

As the modeling is implemented, there will be some iteration between steps in the sequence. It is expected that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. It is envisioned that communication and interaction will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables for review and discussion.

Graded Approach

A graded approach is proposed to undertake the modeling analyses (USEPA 2002, 2009). This graded approach will:

- Use relatively simple methods for initial calculations under the premise that the inherent conservatisms are protective of groundwater and other receptors. Increasing simulation rigor will only be used, if necessary, if simpler approach(es) yield unreasonable results.

- Provide a mechanism to cease model calculations if it becomes evident that no further calculations are necessary. For example, saturated zone flow and transport calculations will only be undertaken if geochemical and vadose zone modeling calculations suggest that a potentially measurable impact to groundwater could occur.

The modeling approach and specific model calculations will be designed to incorporate the principal FEPs while mitigating the potential for computationally-intensive calculations that prevent a thorough exploration of parameter variability and scenario uncertainty. Multiple scenarios will be simulated to evaluate the potential impact of scenario uncertainty on model outcomes, while sensitivity analysis will be used to evaluate the potential impact of parameter variability on model outcomes.

Modeling analyses will be designed to predict the concentration of radium in groundwater for a period of 1,000 years. Concentrations will be forecast at defined compliance locations including, but not limited to, the property fence line/boundary, for the 1,000-year period and will be compared to regulatory standards. If regulatory standards are not exceeded then no further analyses will be required. However, if simulated concentrations exceed regulatory standards, the graded approach will be used to identify the technical element of the modeling approach that incurs the most inherent conservatism in the calculations so that element of the modeling approach can be treated more rigorously to reduce that inherent conservatism (Dixon et al, 2008). If the graded simulation approach has been applied until all inherent conservatisms have been reduced or eliminated, yet simulated concentrations exceed regulatory standards, then this will be considered to be a reliable result.

Simulation Code Selection

Table 1 outlines primary events and processes that will be considered in the calculations. The range of potential outcomes will be evaluated by performing several model simulations that consider reasonable alternate conceptualizations of subsurface conditions. Since parameterization of the geochemical component of the model is likely subject to more variability and uncertainty than the groundwater flow component of the model - given the large number of chemical processes that potentially affect radium fate and transport – advective-dispersive migration will be simulated as one-dimensional (1-D), coupled with a rigorous treatment of the complex geochemical processes. The following sequential series of calculations is proposed to collectively comprise the model [consistent with the graded approach, some calculations will only be undertaken if necessary based on the results of preceding calculations]:

1. The Hydrologic Evaluation of Landfill Performance (HELP) code will be used to determine the run-off component of the surface-water balance and remaining water available for infiltration through cover materials under current conditions, final cover conditions, and following the period of active cover maintenance;
2. HYDRUS 1-D (Simunek et al., 1998) will be used to simulate the water balance in the subsurface (after run-off has been accounted for) and the migration of infiltrating water;
3. The USGS-supported geochemical simulation software, PHREEQC (Parkhurst and Appelo, 1999), which is linked to HYDRUS through the HP1 program (Jacques and Simunek, 2005), will be executed simultaneously to provide concentrations of radionuclides in the leachate as it moves within the unsaturated refuse and underlying unsaturated alluvium;
4. The depth of penetration of any leachate that reaches the water table will be calculated using an established method such as that detailed by USEPA (2000~~1996~~);
5. PHREEQC, linked with HYDRUS, will then be used to calculate the effects of mixing on geochemistry that occurs between the leachate and groundwater at the water table;
6. Output from these calculations will provide the time-varying groundwater composition for simulating 1-D radionuclide fate and transport within the saturated zone toward the Missouri River using PHREEQC; and
7. PHREEQC will be used to represent geochemical processes that may occur within the hyporheic zone of the Missouri River.

Commented [E6]: Why cite the chemical Soil Screening Guidance from 1996 instead of the radionuclide Soil Screening Guidance from 2000. The 5 soil to groundwater models in that document should all have been considered for this effort. http://www.epa.gov/superfund/health/contaminants/radiation/radssg.htm

Overview of HELP Calculations

HELP (Schroeder, P.R. et al, 1994a, 1994b; Berger, 2011; Berger and Schroeder, 2012) is a program originally developed by USEPA to evaluate the effectiveness of landfill cover designs. HELP will first be used to estimate the typical, quasi-steady-state surface-water balance, emphasizing the run-off rate and the net water available for infiltration through the current landfill cover. The purpose of these calculations is solely to support validation of the modeling approach and constrain the values of certain parameters to be consistent with historical water samples. HELP will then be used to make similar calculations to estimate run-off and the net water available for infiltration through the new landfill cover that would be constructed under the ROD-selected remedy, and to estimate run-off and the net water available for infiltration through the new cover following the period of active maintenance. Alternate periods of active maintenance may be considered in alternate simulation scenarios. The HELP model can explicitly account for rainfall-runoff under alternate cover designs, including alternate slopes (grades).

Overview of HYDRUS 1-D Calculations

HYDRUS-1D (Simunek et al., 1998) is a public domain Windows-based modeling environment that simulates the movement of water, heat, and multiple solutes in variably saturated media. The flow equation formulation in HYDRUS incorporates a sink term to account for water uptake by plant roots, as well as a dual-porosity type flow capability in which one fraction of the water content is mobile and another fraction is immobile. The solute transport equations consider advective-dispersive transport in the liquid phase, as well as diffusion in the gaseous phase. HYDRUS 1-D (Simunek et al., 1998) will be

used to simulate the water balance in the subsurface (after run-off has been accounted for), and the migration of infiltrating water.

HYDRUS 1-D is linked to PHREEQC through the HP1 modeling software (Jacques and Simunek, 2005). This allows simulation of complex bio-geochemical reactions. Consistent with the graded modeling approach, the initial simulations will assume that radionuclide attenuation in landfill leachate only occurs in groundwater. However, the HP1 software may be used to estimate attenuation in the non-radiologically impacted refuse and unsaturated alluvium underlying Areas 1 and 2 if unreasonable results are obtained using the more conservative simplifying assumption.

Overview of PHREEQC Calculations

Geochemical modeling will first be completed to estimate the leaching potential of various radionuclides under current site conditions. The purpose of these calculations is to support validation of the groundwater modeling approach and constrain the values of certain parameters to be consistent with historical water samples. Following these calculations, the modeling will be used to evaluate the leaching potential under long-term future conditions under the ROD-selected remedy.

Geochemical modeling methods to estimate source term concentrations for the radio-isotopes will primarily rely upon equilibrium thermodynamics and will be based upon mineral solubility relationships using current ground water compositions. Calculations will be performed using PHREEQC (Parkhurst and Apello, 1999). Solubility calculations for end member phases will be used for thorium and uranium. Radium will be assumed to be present as a solid-solution in barite with a lower thermodynamic activity. Solubility constants for uranium and thorium will, for the most part, be based upon the OECD NEA compilations (Guillaumont et al., 2003; and Rand et al., 2008). Other data sources will be used as needed (Dong and Brooks, 2006, 2008; Duro et al., 2006; Langmuir, 1978; Tokunaga et al., 2009). The ingrowth of ^{226}Ra from ^{230}Th is a time dependent process and the kinetics capabilities in PHREEQC will be used to estimate the production of ^{226}Ra for a period of 1,000 years.

1-D transport modeling will also be performed with PHREEQC. Modeling will simulate a chemical system that is sufficiently complex to include the effects of landfill and groundwater geochemistry described above. Site-specific groundwater and soil data for uranium, thorium, and radium will define initial concentrations for these isotopes. The site analytical results, particularly the groundwater analyses, will also provide details on the overall geochemical environment of the landfill. The PHREEQC fate and transport model will include the following features:

- The effect of radium in-growth from the decay of thorium over time;
- Decreased methane generation and a possible change in site redox conditions from the reducing conditions currently present at the site to more oxidizing conditions;
- Radionuclide precipitation and/or co-precipitation, such as the partitioning of radium into calcite (Yoshida et al., 2008) present within the landfill;
- Changes in iron stability and potential precipitation of iron-bearing phases for the adsorption of radionuclides; and

- Adsorption reactions (surface complexation and ion exchange) (Dzombak and Morel, 1990; Mahoney et al. 2009a, b; Rojo, et al., 2008; Pabalan et al., 1998).

Model Validation and Predictive Sensitivity Analysis

Historical groundwater data have exhibited few detections of radionuclides. As such, a rigorous calibration exercise is not warranted or justifiable. However, the historical data will be used to validate the modeling calculations and potentially bound the values of some parameter combinations by simulating current conditions prior to undertaking predictive calculations. Multiple simulations will be conducted to evaluate the range of forecasts of possible impacts on groundwater beneath the landfill, at the property fence line/boundary, within surface water, at any defined receptors, and at any other locations of interest. Multiple scenarios will be simulated and predictive sensitivity analyses will be used to evaluate the potential impact of parameter variability on model outcomes at these locations. Although outside the scope of the proposed modeling task, the results of multiple-scenario and parameter-/prediction-sensitivity analyses can help guide the sampling frequency for long-term monitoring programs by providing a range of possible arrival-times and peak-concentrations for contamination at identified compliance locations such as the property fence line/boundary.

Deliverables

The final deliverable anticipated to be developed from the modeling effort is a Technical Memorandum documenting the technical approach, assumptions, model development, parameterization, simulated scenarios, and results obtained. However, it is anticipated that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. Communication and interaction with USEPA will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables to USEPA for review and discussion.

No revisions to the SFS report are expected to be required as a result of this modeling effort.

Schedule

It is anticipated that the geochemical evaluation of potential leaching of radionuclides, including preparation and submittal of the Technical Memorandum, will be completed within twelve weeks of the approval to proceed.

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Commented [E7]: Note that there are only 3 EPA guidance documents cites, and one of them (SSG) is clearly the wrong guidance to cite when there is a 2000 version for addressing radioactive contamination. I would also suggest reviewing at a minimum the ORD report that is the basis for the analysis of the 5 soil to groundwater models in the rad SSG. http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/900G0V00.pdf

West Lake Landfill Work Plans

1. Work plan on Partial Excavation Alternative.
   a. "Introduction"

An approach that relies on the following language is likely to lead to a result that is inconsistent with the Board's comments and recommendations: "To implement this directive, Respondents therefore need to use the same criteria that were used to define the FS Partial Excavation Alternative to define the scope of the Partial Excavation with Off-Site Disposal Alternative and Partial Excavation with On-Site Alternative requested in EPA's Letter ("Partial Excavation Alternatives") -- that is, the presence of radionuclides with activity levels greater than 1,000 picocuries per gram pCi/g or the presence of downhole gamma readings greater than 500,000 counts per minute (cpm)."

The Board did not use, rely, or support 'the presence of radionuclides with activity levels greater than 1,000 picocuries per gram pCi/g or the presence of downhole gamma readings greater than 500,000 counts per minute (cpm)" as a metric for anything at this site; in fact, the Board did discuss and refer to "HQ guidance provided to evaluate potential PTW at this site (e.g., "material with concentrations at or exceeding 79 pCi/gr of radium 226 and 228 combined, or 79 pCi/gr of thorium 230 and 232 combined")."

As a related matter, the Board's initial observations/comments/recommendations included the following statements: 1) "Why wasn't removal of top couple of feet of dirt to extract hotspots (or range of depths w/ performance measures to support iterative process) considered with cap placement over what remains?" 2) "The Board notes that the 1982 NRC Radiological Survey states that 1) the representation of subsurface contamination based on auger hole measurements in Figures 15 – 19 of that report "are consistent with the operating history of the site, which suggests that the contaminated material was moved onto the site within a few days' time and spread as cover over fill material. Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results." (p. 16). The Board also notes that the most intense gamma peak readings for RIM in Area 2 are located within three feet of the surface (e.g., PVC 7, PVC-10, PVC-11); see Table 6-9 of RI report." 3) "The Board notes that Table 6-8 in the RI indicates that the estimated average total thickness of RIM for Area 1 is 3.37 ft, and 3.73 for Area 2; this is further supported by Table 5 attached to the 1982 NRC report. The RI report also indicates that "Based upon the radiological data, McLaren/Hart concluded that the zone of radiological impacts in Area 1 is generally a thin layer (5-feet thick or less) in the upper part of the landfill debris" (page 32) and "Based upon the radiological data, McLaren/Hart concluded that the zone of radiological impact in Area 2 is generally a thin layer (less than 5 feet) in the upper part of the landfill debris" (page 33). This conclusion is similar to the one made by the NRC in its 1982 Radiological Survey that the deposits appear to form "a fairly continuous, thin layer of contamination, as indicated by survey results (page 16) and "a contiguous layer" (page 21), reflected also in Figures 10 – 19 attached to that report which include a number of cross-section diagrams." 4) "Also, the Board notes that the RI report states that "Based upon the results of the downhole gamma logging and the laboratory analyses, radiologically impacted materials were generally found at depths ranging between 0 to approximately 6 feet in the northern portion of Area 2" and "In the southern part of Area 2, radiologically impacted materials were identified at depths generally ranging between 0 and 6 feet." (RI page 97)." 5) "The Board recommends that the Region develop an alternative that reflects an approach which surgically removes the RIM, which appears to be a discrete, reachable source term that will continue to increase in toxicity over hundreds and thousands of years, in a calibrated manner using performance standards for the excavation process that excludes material not contaminated by the RIM (e.g., construction debris in the overburden material). In addition the Board recommends that the Region develop an alternative that would utilize construction of an engineered cell (even if one would not be located on-site but in the vicinity), as well as disposal of the RIM at Weldon Springs (where other Latty Avenue radioactive waste was disposed of)."

b. "Approach"—

The work plan says: "Specifically, excavation and final grading plans will be prepared for the Partial Excavation Alternatives based on the criteria listed above." For the reasons explained above, using the "criteria listed above" does not reflect the Board's expressed concerns.

The work plan also says: "The thickness of cover material necessary to provide protection against gamma radiation and radon emissions under the Partial Excavation Alternatives will be calculated using the same approach as was used in the SFS for evaluation of the cover thickness for the ROD-selected remedy." The Board did make a number of comments concerning a cover or cap at this site, including: 1) "Both of these landfill designs as a preferred remedy has shortcomings for rim waste alone and in a humid region. A comparison of various landfill capping designs addressing both humid region conditions and long term protection from rim (1000 years) would be an important concept for the preferred remedy. However, the package did not appear to include alternative cap designs, i.e., EPA landfill cap guidance design, existing cap designs for similar rim Weldon Springs), or evapotranspiration cover cap system designs (OSWER Fact Sheets: EPA 5420F-03-015, 2003; EPA 542-F11-001, 2011). For example; a Subtitled C/UMTRCA hybrid may be suitable for both long term infiltration management and radiation shielding protection, The Board recommends that the region include in its remedy selection process evaluations of cap designs similar, but not limited to the above conditions and guidances." 2) "The package presented to board described the preferred remedy as a hybrid cap/cover design incorporating both Subtitle D and UMTRCA cover design features applied to an existing unlined landfill. However, the package lacked sufficient information on the long term protectiveness of the preferred remedy. Specifically, how the preferred remedy remains protective given the increasing daughter ingrowth concentrations of radium 226/228, radon 222, and the increase in toxicity over time (1000 years)." 3) "Thus, the Board questions the appropriateness of using regulatory standards designed for municipal solid waste for RIM at levels currently measured at 57,300 pCi/gr (page 44 of the package), and expected to peak at over 700,000 pCi/gr, as ARARs, especially where Areas 1 and 2 were not permitted as subtitle D landfills or licensed as an NRC facility. The Board is not aware of other sites where subtitle D standards have been considered as the correct benchmark for management of waste like the RIM at this site." 4) "The packaged presented to the board indicated that the preferred remedy alternative was based on a Subtitle D/UMTRCA Hybrid cap design. Each of these landfill designs as a preferred remedy has shortcomings for rim waste alone and in a humid region. A comparison of various landfill capping designs addressing both humid region conditions and long term protection from rim (1000 years) would be an important concept for the preferred remedy. However, the preferred remedy package did not appear to include related cap designs, EPA landfill cap guidance, or existing cap remedies for similar rim. For example; a Subtitle C/UMTRCA hybrid may be suitable for both long term infiltration management and radiation shielding protection, evaluation of recent evapotranspiration cover cap system designs (OSWER Fact Sheets: EPA 5420F-03-015, 2003; EPA 542-F11-001, 2011) are important cap design concepts, and review of the existing DOE cover cap design at Weldon Springs for similar rim and climatic conditions may be useful in such a comparison. The Board recommends that the region include in its remedy evaluations cap designs that reflect the above conditions and guidances but not necessarily be limited to these examples, in order to ensure all potential alternatives are fully evaluated for purposes of cost, implementability, and other factors." Since the Board expressed concern about the proposed approach taken with regard to the cap, "using the same approach as was used in the SFS" is likely to leave the Board's concerns unaddressed.

c. "References" –

The work plan refers to two documents, the 2011 SFS and the 2006 FS. The Board repeatedly indicated that the two NRC reports should be used. The Board also referred to relevant information in the RI. Not using the 2 NRC reports and the RI, and the comments and recommendations the Board made using those three documents, is likely to result in a product that does not address the Board's comments and recommendations contained in the February, March, April and May versions of the Board memo that was distributed to all members.

2. Work plan on Evaluation of the Use of Apatite/Phosphate Treatment Technologies.

   a. "Introduction"

The work plan says: "EPA has asked the Respondents to evaluate the potential application of apatite and/or phosphate solutions for possible treatment of waste materials and/or groundwater. EPA requested that this evaluation be performed at a level of detail comparable to that used to evaluate the treatment technologies previously analyzed in the SFS."

The Board discussed a range of possible treatment technologies during the review, and also in versions of the Board memo. Examples of draft recommendations include: 1) "Why aren't we undertaking dry soil separation? We understand that due to sulfates being present, solidification may not work. Since there are PTWs, per guidance, Region should explain why treatment is not occurring." 2) "The Board notes that several treatment technologies were evaluated and screened out during the FS process., Whether the radioactive waste (change to RIM) resides in a heterogeneous or homogeneous distribution, volume separation techniques (volume reduction) and offsite disposal in a dedicated and regulated radioactive disposal unit may result in a more permanent remedy if short-term risks are minimized by engineering controls, personal protection equipment, or administrative controls, as well as if the radioactive waste is able to be physically sorted from the other waste in the landfill. If the radioactive waste can be detected and distinguished by emission signals and resides in distinct homogeneous layers, field screening techniques can be used for isolation followed by removal. If the waste resides in a more heterogeneous distribution, commercial sorting technologies, using multiple scanning spectroscopic techniques (that are used on DOE sites such as the MACTEC ScanSort process, or the EBERLINE Segmented Gate System) should be considered and evaluated. These processes could also be considered if a portion of the surface radioactive waste is planned to be consolidated under the final cover. The Board recommends that more explanation be provided for ruling out an in situ solidification/stabilization process specifically designed for both high sulfate content and saturated conditions as well as the separation techniques. The Board also recommends that the Region consider using S/S as a layer included in the cap design." 3) "The Board notes that "treatment" can include measures taken to reduce volume, as well as solidification technologies designed to immobilize constituents of concern. The Board recommends that the Region develop an alternative based on a re-examination of potential treatment technologies that could be used at this site, including specifically methods of sorting through overburden and RIM to reduce the overall volume. This is especially true for the RIM in Area 2, since it appears that "construction fill" (as opposed to "sanitary" fill) was added to cover the contamination on this portion of the site, and Area 2 contains the majority of the RIM and overburden." It is not clear why only apatite/phosphate treatment technology is being evaluated.

b. "Approach"

The work plan relies on literature search and discussions with DOE, rather than a bench scale or pilot approach geared to site-specific circumstances and actual RIM that is present at this site. It is not clear that the approach to be taken would yield useful information.

c. "Results of Preliminary Evaluations"

The work plan says: EPA previously determined that there is no unacceptable risk of groundwater contamination at the site. Specifically, the ROD contains the following conclusions:

1. *These* (groundwater sampling) *results are not indicative of on-site contaminant plumes, radial migration, or other forms of contiguous groundwater contamination that might be attributable to the landfill units being investigated.* (ROD at p. 20)

2. *The groundwater results show no evidence of significant leaching and migration of radionuclides from Areas 1 and 2.* (ROD at p. 21)

3. *Significant leaching and migration of radionuclides to perched water or groundwater have not occurred despite landfilled waste materials having been exposed to worst-case leaching conditions from surface water infiltration over a period of decades.* (ROD at p. 21)

4. *The lack of radionuclide contamination in groundwater at the Site is consistent with the relatively low solubility of most radionuclides in water and their affinity to adsorb onto the soil matrix.* (ROD at p. 21)

5. *This pathway for migration* (groundwater flow to the river) *is not considered significant under current conditions because the on-site impact to groundwater from the landfill units is so limited.* (ROD at p. 21)

6. *The fourth* (remedial action) *objective* (Collect and treat contaminated groundwater and leachate to contain any contaminant plume and prevent further migration from the source area) *is not applicable because a plume of contaminated groundwater beneath or downgradient of the disposal areas has not been identified.* (ROD at p. 30)

Consequently, groundwater was not determined to be a media of concern (i.e., no plume of groundwater contamination exists) and treatment of groundwater was not identified as a potential response action for the site in the prior FS or SFS."

Board comments during the meeting and in draft versions of the memo both indicate that the Board did not necessarily agree with these statements in the ROD or find them persuasive (the 2008 ROD was not reviewed by the Board), and had concerns and recommendations regarding the approach taken for ground water contamination at this site, including: "Based on the information presented to the Board, it appears that there have been some samples of groundwater at this site that exceed standards considered as ARARs. The Region also stated that no discernable plume at this site has been identified, and its preferred approach is to continue monitoring groundwater. Generally, under existing Agency guidance, exceeding a maximum contaminant level in groundwater normally would warrant a response action (OSWER Directive 9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection* Decisions and OSWER Directive 9283.1-33 *Summary of Key Existing EPA CERCLA Policies for Groundwater* Restoration). The Board recommends that the Region consider additional wells at the site to better delineate the vertical and lateral extent of potential site-related contamination previously indentified from limited sampling in Area 1 and especially Area 2. These additional wells would be instrumental in clarifying the presence of an isolated groundwater hot-spot versus a groundwater plume in the complex subsurface geologic setting. The general recommendation is that the additional wells be nested along the western border (Crossroad property) of Area 2 in the unconsolidated alluvial deposits and the underlying fractured and vuggy, limestone Keokuk formation. In light of these facts, the Board notes that the Agency's long-standing policy has been that monitoring by itself is not a CERCLA remedial action, and believes that the information submitted to the Board may not support a conclusion that monitoring to evaluate effectiveness of the source control remedy (if that approach is selected) would constitute an effective or final ground water response action for this site. As such, the Board recommends that the decision documents clearly explain the role of monitoring in the Region's preferred approach, and indicate that any potential groundwater cleanup would be addressed in a separate decision document in the future representing a final ground water remedial action, should one be needed. In addition, the package at page 22 states that "Only four wells exhibited a total radium concentration above 5 pCi/l. These exceedances ranged from 5.74 pCi/l to 6.33 pCi/l. The slight exceedances are isolated spatially. Two of the four wells with total radium exceedances are located in areas that are not downgradient of either Radiological Area 1 or Radiological Area 2." The chart on page 21, however, indicates that there were two wells with exceedances and that the maximum detected concentration was 8 pCi/l. The Board recommends that the Region reconcile these discrepancies." Taking an approach based on these statements may lead to a result that does not address the Board's concerns and recommendations.

d. "References"

See comments above. Also, in the Technical References section, it appears that the documents listed may relate to potential use of apatite treatment technology for uranium contamination (for example, at Hanford); since this site involves radium contamination, it is not clear how relevant such documents would be.

3. Work plan on Alternative Area 2 Excavation Depths and Volumes.

a. "Introduction"

The work plan says: "EPA has asked that the volume of radiologically-impacted material (RIM) considered for possible excavation under the "complete rad removal" alternatives be revised to exclude deeper intervals in soil borings WL-210 and WL-235 in Area 2."

The Board during its discussions and deliberations during the meeting, and in drafts of the Board memo, was concerned that the "complete rad removal" approach being followed at this site overstated the volume and extent of contamination, as reflected by a number of statements including: 1) "In addition, the SFS (p. 62) indicates that "the cleanup standards to be used for the development and evaluation of the 'complete rad removal' are background-based standards." The SFS also appears to have used unrestricted land use in estimating the volume of RIM that would have to be removed under a "complete rad removal" scenario. The Region indicated that the West lake landfill property is zoned industrial/commercial, and will stay that way. The Board believes that using background-based standards and unrestricted use leads to unnecessarily overstating the volume of RIM that would have to be excavated and treated under a "complete rad removal" alternative. In particular, the Board notes that a "do not exceed" 5 pCi/gr approach throughout the landfill would be unreasonable and extreme (i.e., not every last molecule needs to be removed from the landfill), unless the reasonably anticipated future land use might be "residential," which appears unrealistic." 2) 'In light of its other comments, the Board notes that it appears that the 500,000 cubic yards amount corresponding to the "complete rad removal" option likely overstates the volume and cost associated with a reasonable excavation remedy, especially where it appears feasible to separate out uncontaminated overburden material (e.g., construction debris)."

The work plan also says:" Although the RI raised possible questions about the representativeness of the downhole gamma logs for the deeper intervals of these two borings, a soil sample obtained from boring WL-210 detected the presence of total Thorium-230+232 at a depth of 40 ft bgs at a level (18.6 pCi/g) above the cleanup level (7.9 pCi/g) used to evaluate potential excavation alternatives. A duplicate sample obtained from this same depth interval contained total thorium at 11.6 pCi/g. These samples were obtained from a depth of 40 ft, 10 feet above the bottom of the borehole. In addition, these samples were obtained during drilling of the borehole, prior to the downhole logging activities that may have resulted in surficial material being knocked into the hole. Therefore, these sample results likely represent actual conditions at the 40 ft depth interval in boring WL-210. The RI sampling did not include collection of a soil sample from the deeper portion of the WL-235."

The Board raised a number of concerns with the way the nature and extent of RIM at the site was characterized, and made several detailed statements on the subject, including: 1) "The Board is concerned that the data from these borings does not support the FS/SFS, the package, the ROD, and the Region's findings and preferred approach." 2) "The Board believes that these discrepancies are significant for many reasons. It appears that the specific boring data referred to by the Region may not accurately depict the actual scope and vertical extent of RIM at this site. The Board is concerned that inclusion of such inconsistent data negatively impact the alternatives evaluation process (including how the cost and feasibility of various implementation options have been evaluated), and led to a preferred alternative that may not be the most protective or cost effective. The RI and NRC data appear to suggest that most of the RIM is located closer to the surface of the landfill (i.e., within 10 feet). The Board recommends that the Region carefully re-consider and re-evaluate the data and information contained in the NRC and RI reports to ensure that the nature and extent of RIM are accurately characterized and recommends that the Region re-evaluate potential alternatives based on the more likely location of RIM at the site. This re-evaluation should also consider the presence of hot spots that could be targeted for excavation. The Board believes that hot spot removal is consistent with ongoing cleanup of rad sites in several other Regions. Specifically, in Region 2, reduction of rad-impacted source material is being undertaken in a manner that is protective and without short-term impacts, where the Region determined that eliminating the source is an important objective of the cleanup. The Board notes that the cut-off levels (e.g., 100 pCi/gr, and especially 1000 pCi/gr) analyzed in the FS for identifying "hot spots" and evaluating excavation options (e.g., section 4.4.4.1.6 starting on page 83) appear to be out of step with EPA positions regarding protective cleanup decisions involving radioactive material at other sites, and inconsistent with HQ guidance provided to evaluate potential PTW at this site (e.g., "material with concentrations at or exceeding 79 pCi/gr of radium 226 and 228 combined, or 79 pCi/gr of thorium 230 and 232 combined")."

The work plan, in the way it discusses WL-210 and WL-235, as well as thorium levels of 18.6 pCi/g and 11.6 pCi/g, does not appear to reflect an understanding of the full range of the Board's concerns. One way to avoid misunderstanding the Board's concerns would be to provide the early versions of the Board memo which went into more detail than later versions, so that there can be a clear and complete description of all of the comments and recommendations made based on the meeting.

b. "Approach"

The work plan says: "...consequently to eliminate removal of the deeper interval of RIM material from the southwestern portion of Area 2;" and "...revised cost estimates for excavation and offsite or onsite disposal based on exclusion of the potential deeper occurrences of RIM beneath the southwestern portion of Area 2." These statements do not necessarily accurately reflect the Board's comments and recommendations, and may lead to a result that does not address the Board's concerns.

c. "Deliverables"

A number of statements are made in this section that may not necessarily accurately reflect the Board's comments and recommendations, and may lead to a result that does not address the Board's concerns.

d. "References" – see comments above.

4. Workplan on Additional Present Value Cost Estimates.

The Board's comments and recommendations on this issue appear straightforward in the various versions. To the extent the work plan calls for deliverables that are based on " the ROD-selected remedy and the two "complete rad removal" alternatives presented in the SFS" and does not reflect Board comments and recommendations on those, it may lead to a result that does not address the Board's concerns.

West Lake Landfill
Scope of Work: Alternative Cover Designs and Fate and Transport Modelling

Alternative Cover Designs

- Not sure why an ET Cover is even being considered at the site since its deficiencies have already been identified (Albright and Benson).
- Disposal of similar waste at Weldon Springs has an established cover design with a proven performance history that should be considered. While the Weldon springs cover might appear as over-engineering, components of the system are effective and could reduce cost and material mass tot eh West Lake cover.
- The option of evaluating a more protective RCRA cover should be considered. While a RCRA Subtitle C cover system might be very conservative it does compensate for the lack of a liner system with leachate collection.
- The lack of a cover system that uses a geosynthetic liner is missing. While there are limitations to solely using a geosynthetic liner, proper engineering allows for effective performance.

Fate and Transport Modeling

- The use of the various models should be sufficiently flexible to accommodate the range of landfill system specifications, identified in the SCOPE and suggested above.
- The assumption of future radium decay needs to be critically evaluated and accounted for.
- While the SCOPE discusses simulating future climate conditions and subsequent infiltration, the inclusion of resident moisture need to accounted for in all simulations.
- The incorporation of a colloidal transport simulation should be included since it has been already identified that the depth of contaminant is selected area was deeper that expected due to aqueous transport.
- The statement indicating that co-precipitation is expected to be a dominant process appears to be a bit premature and unsupported.
- The statement regarding the influence on increasing pH is unusual. While it is recognized that biodegradation processes will general result in reduced redox and pH; without an alkaline source, the pH in the aqueous environment will be challenged to increase above neutral pH, and likely to remain less than neutral.
- The "Graded Approach" looks to be a reasonable approach to the addressing he modeling issue.
- While this effort is solely identified as modeling, it was be remiss to not include corroboration of the modeling with supporting groundwater monitoring well data. Just caution on the elimination of pathways too earnestly. Should establish an "accepted" criteria for discontinuing model runs.
- The most controversial areas at West Lake LF would benefit from the installation of additional groundwater monitoring wells, especially in the 'washout' area and along Charles Road where groundwater-surface water interface occurs.
- While not adverse to the use of the following models: HELP, HYDRUS and PHREEQC, all well known to the commenter. It might be constructive to use some other models that are EPA supported (e.g., MINTEQA2)

Scope of Work and Schedule

Fate and Transport Modeling

Introduction

The U.S. EPA's October 12, 2012 letter (USEPA, 2012) requested that the Respondents perform fate and transport modeling at the West Lake Landfill (the Site). This Scope of Work (SOW) describes the modeling approach proposed to estimate potential fluxes of landfill leachate, possible radionuclide concentrations within the leachate, and the potential for transport of any radionuclide-contaminated leachate within the subsurface.

This SOW first outlines the objectives of the proposed modeling task. This is followed by a discussion of the general conceptual site model (CSM). Features of the Site that are expected to be simulated are described together with potential events and the physical and chemical transport processes that are envisioned as being incorporated in the modeling analyses. After describing the CSM and defining the objectives of the modeling calculations - which together define the necessary capabilities of the developed model – the calculation approach and the simulation programs proposed to meet the modeling objectives are identified. The final suite of scenarios to be simulated will be determined as part of the model implementation task.

It is assumed that modeling calculations will be performed on the basis of existing site-specific data, augmented where necessary with information and values obtained from technical literature and/or derived from professional experience.

Background

West Lake Landfill is located within the western portion of the St. Louis metropolitan area approximately two miles east of the Missouri River. Two areas of the Site contain radionuclides as a result of the use of soils mixed with leached barium sulfate residue as cover for municipal refuse. The Site is divided into two Operable Units (OUs). OU-1 consists of the two areas within the landfill where radionuclides are present and the area formerly described as the Ford Property, now called the Buffer Zone/Crossroad Property. OU-2 consists of other landfill areas that are not impacted by radionuclides (USEPA, 2008). Modeling calculations proposed in this SOW address the potential fate of radionuclides within OU-1. The nature and extent of radionuclides within OU-1 are discussed in several documents included in the administrative record for this site, including the Remedial Investigation (EMSI, 2000) and a Supplemental Feasibility Study (SFS) (EMSI, 2011) for OU-1.

~~The selected remedy for OU-1 presented in the Record of Decision (ROD) includes source control through containment of waste materials and institutional controls for the landfilled waste materials (USEPA, 2008). Components of the ROD-selected remedy include the following:~~

Commented [cao1]: Not sure what this letter is based on as far as Board recommendations is concerned since no final Board memo had been sent by this date --

Commented [cao2]: Board's draft recommendations prepared between February and May 2012 recommended gathering additional data to ...

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Commented [cao3]: In several places, language appears inconsistent with Board's spring 2012 draft recommendations. For example, "within the landfill" together with "as cover for municipal refuse" in the previous sentence, and statements made on page 4 below, seems inconsistent with the Board's initial observations/comments/recommendations contained which included the following statements: 1) "The Board notes that the 1982 NRC Radiological Survey states that the representation of subsurface contamination based on auger hole measurements in Figures 15 – 19 of that report "are consistent with the operating history of the site, which suggests that the contaminated material was moved onto the site within a few days' time and spread as cover over fill material. Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results." (p. 16). The Board also notes that the most intense gamma peak readings for RIM in Area 2 are located within three feet of the surface (e.g., PVC 7, PVC-10, PVC-11); see Table 6-9 of RI report." 2) "The Board notes that Table 6-8 in the RI indicates that the estimated average total thickness of RIM for Area 1 is 3.37 ft, and 3.73 for Area 2; this is further supported by Table 5 attached to the 1982 NRC report. The RI report also indicates that "Based upon the radiological data, McLaren/Hart concluded that the zone of radiological impacts in Area 1 is generally a thin layer (5-feet thick or less) in the upper part of the landfill debris" (page 32) and "Based upon the radiological data, McLaren/Hart concluded that the zone of radiological impact in Area 2 is generally a thin layer (less than 5 feet) in the upper part of the landfill debris" (page 33). This conclusion is similar to the one made by the NRC in its 1982 Radiological Survey that the deposits appear to form "a fairly continuous, thin layer of contamination, as indicated by survey results (page 16) and "a contiguous layer" (page 21), reflected also in Figures 10 – 19 attached to that report which include a number of cross-section diagrams." 3) "Also, the Board notes that the RI report states that "Based upon the results of the downhole gamma logging and the laboratory analyses, radiologically impacted materials were generally found at depths ranging between 0 to approximately 6 feet in the northern portion of Area 2" and "In the southern part of Area 2, radiologically impacted materials were identified at depths generally ranging between 0 and 6 feet." (RI page 97)."

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Commented [cao4]: In light of Board's 2012 review (plus original reasons for doing the SFS), this next paragraph seems out of place/confusing/potentially misleading,

1. ~~A new landfill cover over the existing surface of Areas 1 and 2;~~
2. ~~Consolidation of radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;~~
3. ~~Groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;~~
4. ~~Surface water runoff control;~~
5. ~~Gas monitoring and control including radon and decomposition gas as necessary;~~
6. ~~Institutional controls; and~~
7. ~~Long-term surveillance and maintenance of the remedy.~~

A ROD was signed in 2008. In addition, an SFS done in 2011 discussed potentially appropriate Pperformance standards for cleanup of this site. ~~for these remedy components are detailed in the ROD. The following additional performance standards were also identified for the OU-1 remedy~~ (EMSI, 2011):

- ~~The proposed~~ A cap that ~~should~~ would meet the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions;
- ~~Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations;~~
- Groundwater monitoring that would ~~should~~ be implemented at the waste management unit boundary and at off-site locations; and
- Flood control measures at the Site that would ~~should~~ meet or exceed design standards for a 500-year storm event under the assumption that the existing levee system is breached.

~~As defined in the OU-1 ROD, the new landfill cover for Areas 1 and 2 would consist of the following, from bottom to top: 2 ft of rock consisting of well-graded pit run rock and/or concrete/asphaltic rubble ranging from sand-sized up to 8 inches; 2 ft of compacted clay or silt that when compacted at optimum moisture content possesses a coefficient of permeability of 1 x 10^-5 cm/sec or less; and 1 ft of soil suitable of supporting vegetative growth. These layer thicknesses are based on requirements of the Missouri Solid Waste Rules and the description of the cover system in the ROD (USEPA, 2008).~~ [A separate task will evaluate potential alternative landfill cover designs other than those discussed in the 2008 ROD, including possible use of an Evapotranspiration (ET) cover or ~~incorporation of a~~ geomembrane ~~into the design of the ROD-selected landfill~~ cover.]

Modeling Objectives

The proposed fate-and-transport modeling will provide site-specific calculations of the potential for radionuclides to leach from the landfill, reach the underlying saturated aquifer, and result in unacceptable concentrations within groundwater or surface water downgradient of the landfill. The following modeling objectives are proposed:

1. Calculate the potential for migration of leachate containing radionuclides from waste materials:
    a. Under current conditions, to validate the modeling approach and potentially bound parameter values for later predictive analyses;

Commented [cao5]: Board has said in its memos that monitoring by itself is not a CERCLA remedy (so could not be a "component of the ROD selected remedy"

Commented [cao6]: Not sure what this means --

Commented [cao7]: This makes it sound like they have been selected as part of the remedy – ROD would do that, not SFS (if the EMSI reference is to SFS)

Commented [cao8]: If this is the SFS, should identify it as such

Commented [cao9]: Not sure what this "proposed" refers to --

Commented [cao10]: How is this relevant to this SOW for ground water? Board recommendations on ground water don't address air do they?

Commented [cao11]: Again, as Board has stated, monitoring by itself is not a remedy, so not clear what performance standards (as discussed in the NCP) would be for here --

Commented [cao12]: The Board's draft recommendations from spring of 2012 questioned use of state's subtitle D regs --

Commented [cao13]: See comment 4

Commented [cao14]: Should explain why this might be relevant to ground water SOW --

Commented [cao15]: The Board's draft recommendations from spring of 2012 included other things that are relevant to this SOW for ground water, including language from the initial draft ("Groundwater: monitoring wells placed in perimeter fashion; dated GW data—gather new data now; wells seem to be clustered—large gaps—need wells in between gaps to determine if there is, in fact, a plume issue (e.g., predesign installation of new wells); if we can't fully characterize GW, then we need to have a sufficient record to substantiate that conclusion"), as well as later versions which said: "Based on the information presented to the Board, it appears that there have been some samples of groundwater at this site that exceed standards considered as ARARs. The Region also stated that no discernable plume at this site has been identified, and its preferred approach is to continue monitoring groundwater. Generally, under existing Agency guidance, exceeding a maximum contaminant level in groundwater normally would warrant a response action (OSWER Directive 9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection* Decisions and OSWER Directive 9283.1-33 *Summary of Key Existing EPA CERCLA Policies for Groundwater* Restoration). The Board recommends that the Region consider additional wells at the site to better delineate the vertical and lateral extent of potential site-related contamination previously indentified from limited sampling in Area 1 and especially Area 2. These additional wells would be instrumental in clarifying the presence of an isolated groundwater hot-spot versus a groundwater plume in the complex subsurface geologic setting. In addition, the Region should explain why there are numerous decommissioned wells on site. Sampling of these wells may have provided a more complete picture of potential groundwater contamination. The general recommendation is that the additional wells be nested along the western border (Crossroad property) of Area 2 in the unconsolidated alluvial deposits and the underlying fractured and vuggy, limestone Keokuk formation. The Board also notes that the Agency's long-standing policy has been that monitoring by itself is not a CERCLA remedial action, and believes that the information submitted to the Board may not support a conclusion that monitoring to evaluate effectiveness of the source control remedy (if that approach is selected) would constitute an effective or final groundwater response action for this site. As such, the Board recommends that the decision documents clearly ... [1]

b. Under future conditions, assuming the emplacement of a new landfill cover for OU-1; and
c. Under future conditions, following the period of active maintenance of the new landfill cover for OU-1.

2. Calculate the potential for leachate containing radionuclides to migrate vertically through waste that is uncontaminated by radiological constituents and through native materials beneath the landfill, and to impact underlying groundwater;

If the prior calculations indicate that a potentially measurable impact to groundwater may occur:

3. Calculate the likely fate of any radionuclides that reach groundwater, and the potential for the development of a contaminant plume;
4. Calculate concentrations over time of radionuclides in groundwater at defined locations including, but not limited to, the property fence line/boundary; and
5. Evaluate the potential for radionuclides that reach the groundwater to migrate toward, and discharge to, the Missouri River at levels exceeding standards.

These are the specific objectives of the proposed modeling task. The model may, at some later time, be used to support other Site objectives such as (a) designing a suitable groundwater monitoring program, including defining the locations and frequency of sampling to detect any potential off-site migration of radionuclide constituents and/or (b) evaluating alternative landfill cover designs such as an ET cover or incorporation of a geomembrane.

Fate and Transport Conceptual Site Model

Because the overall mass of radium at the Site is small[1] and future infiltration through the landfill materials will be less than at present due to the planned emplacement of an additional landfill cover over the existing landfill cover material, it might be expected that concentrations of radium will necessarily decline in the future. However, site-specific conditions need to be evaluated before reaching this conclusion. For example, uranium and thorium that are present in the waste materials will continue to decay, and in doing so, generate radium. In addition, the landfill and groundwater geochemistry will change over time due to the eventual exhaustion of readily-biodegradable organic matter in the landfill. This will in turn affect the stability of some minerals available to sequester radium.

Selection of an appropriate calculation method, and of a suitable simulation code or suite of codes to implement the calculations, requires that the modeling requirements are defined. In the context of radionuclides, the Nuclear Energy Agency Organization for Economic Co-operation and Development (NEA-OECD, 2000) developed a systematic approach to define relevant scenarios for safety assessment studies at radioactive waste management sites. This consists of identifying and prioritizing the Features,

[1] Using the arithmetic mean concentrations (reported as pCi/gram) from Appendix A of the RI, as well as an estimated mass of soils for the Area 1 and 2 surface and subsurface zones at the West Lake site, a preliminary estimate of the amount of ^{226}Ra at the site indicates that there is less than 40 grams of ^{226}Ra within Areas 1 and 2.

Commented [cao16]: This seems to suggest that it's mass that counts, not risk posed by the rad – based on discussions during the February, 2012 Board meeting and draft recommendations prepared by the Board during the spring of 2012, this statement/approach appears inconsistent with the documents in the administrative record for this site and with the remedial program's approach at rad sites around the country. For example, the Board's draft recommendations stated:
"Finally, the Board notes that the FS (at page 60) stated that "Excavation of a smaller volume of radioactively impacted material [than the estimated 250,000 cubic yards of total RIM plus soil and debris] would not significantly reduce the threat posed by the overall site." The Board is concerned that this kind of approach is inconsistent with, and could undermine, ongoing cleanup of rad sites in several other Regions. Specifically, in Region 2, reduction of rad-impacted source material is being undertaken in a manner that is protective and without short-term impacts, where the Region determined that eliminating the source is an important objective of the cleanup. Region 2 has been removing radiological contamination from residential and commercial properties for the past two decades. That work is undertaken with appropriate engineering controls and in accordance with approved health and safety plans, often with homeowners remaining in their residences during the cleanup effort. These types of cleanups can be safely and efficiently undertaken. Given the presence of highly radioactive material at this site, and the fact that its hazardous nature will continue to increase over time, the Board believes excavating and/or treating any amount of the RIM should lead to important risk reduction. Where it appears that much if not all of the RIM is located near the surface, cleanup at this site appears less complicated than other sites where, for example, buried drums containing liquids have been safely excavated. Radiological material is also easily sorted out in the field with portable instruments that provide instantaneous measurements to ensure that only contaminated material is retrieved which, in turn, minimizes disposal costs."
Saying that "the overall mass of radium at the Site" also could cause confusion/misunderstanding

Commented [cao17]: This is making an assumption about the remedy that doesn't seem to take into account the Board's concerns/ recommendations made in draft memos during spring of 2012 – the Board didn't make its recommendations regarding groundwater based on an additional landfill cover; rather, the recommendations were that there's insufficient data and more data/more wells are needed to adequately characterize the site (see comment 15 for actual wording of Board's spring 2012 1draft recommendations/comments)

Commented [cao18]: This appears inconsistent with Board's views expressed during meeting and in spring 2012 draft recommendations – for example: "Based on the package provided to the Board, it appears that there are potentially significant amounts of RIM that are highly toxic (e.g., based on NRC estimates in the 1982 and 1988 reports, radium of up to 22,000 pCi/gr, bismuth-214 of up to 19,000 pCi/g, and average thorium-230 concentrations of 9000 pCi/gr; the package at page 44 notes that the RI report discussed thorium-230 at levels as high as 57,300 pCi/gr) and that the highest gamma peak intensity readings are at shallow depths. The FS states (page 84) that most of Area 2 contains RIM at above 100 pCi/gr. The NRC reports also disc ... [2]

Commented [cao19]: See comment 17 --

Commented [cao20]: Consistent with Board comments/recommendations made at other rad sites (e.g., Hanford), CERCLA remedy selection should be done using CERCLA rad guidance --

Events, and Processes (*FEPs*[2]) that potentially affect the fate and transport of radionuclides at a site, and developing and modeling individual scenarios, each of which consists of a well-defined, connected sequence of selected FEPs. This SOW identifies principal FEPs for the Site that it is anticipated will require consideration in the modeling analyses. However, the final site-specific FEPs and the suite of simulation scenarios will be defined during the implementation phase of the modeling task.

Primary Site-Specific Features

An overview of the primary features that affect radionuclide fate and transport is provided here. The source of radionuclides of potential concern is leached barium sulfate residue mixed with soil ~~and used as daily and intermediate cover for municipal solid waste deposited in landfill~~ in Areas 1 and 2. ~~This radiologically-impacted material (RIM) is currently covered by old landfill cover material~~. Underlying the RIM is refuse that does not contain radionuclides, and under that is partially saturated alluvium. Over time some fraction of radionuclide-bearing water could potentially percolate vertically to reach the water table. According to the RI [EMSI, 2000], the saturated aquifer largely consists of alluvial sand, underlain by more impervious limestone and dolomite bedrock. The horizontal hydraulic gradient within the aquifer is relatively flat, which would tend to result in slow advection along a trajectory that intersects the Missouri River downgradient of the Site. If radionuclide-containing water currently located within or under OU-1 were to reach the water table beneath the landfill, then mixing, dispersion, and dilution of that radionuclide-containing water would occur at the water table beneath the landfill, within the saturated aquifer, and within the hyporheic zone of the Missouri River.

Commented [cao21]: See comment 3 above --

Commented [cao22]: See Board's spring 2012 draft recommendations/comments describing documents in the administrative record that describe RIM as at the surface in certain locations, and between 0 – 6 feet in many others.

Commented [cao23]: Should it be "and" or should it be "or" ?

Commented [cao24]: This makes it sounds like a certainty – Ron indicated at the Board meeting and other conversations that it might not be so – for example, the fact that Kaarst is a factor, plus the hits above MCL that have been documented in the administrative record might not support this --

A dominant feature [which, depending upon the simulation scenario, may also constitute an event] that must be considered in the modeling calculations, and for which a design is presented in the ROD but for which potential alternatives have since been identified by USEPA for evaluation, is the new landfill cover to be installed over the current surface of the old landfill cover. Modeling calculations proposed under this SOW will only consider the ROD-selected landfill cover, the design of which is detailed above and within the ROD (USEPA, 2008). However, the developed model could be used at some later time to evaluate alternative cover designs such as an ET cap and/or the incorporation of a geomembrane within the ROD-selected landfill cover.

Commented [cao25]: See comment 17 above

Commented [cao26]: See comment 4 above – this approach appears to ignore Board review process and the spring 2012 draft recommendations/comments

Primary Site-Specific Events

Several events may affect the landfill water balance, the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example events are summarized in Table 1.

[2] The following definitions apply (Sandia National Laboratories, 2010):

Feature – An object, structure, or condition that has a potential to affect repository system performance.

Event – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during an interval that is short compared to the period of performance.

Process – A natural or human-caused phenomenon that has a potential to affect repository system performance and that occurs during all or a significant part of the period of performance.

Table 1 Primary Events and Processes of Potential Radionuclide Fate and Transport at the Site.

FEP Element	Description
Events:	1. Transition from current cover conditions to final cover under active maintenance: • Cover design (*2-ft of well-graded pit run rock and/or concrete/asphaltic rubble; 2-ft of compacted clay or silt with a coefficient of permeability of 1 x 10^{-5} cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth*) • Period of active maintenance (*30 yr min/200 yr ROD/1000 yr UMTRA-compliant*) 2. Transition from active maintenance period to post-active maintenance period: • Intermediate infiltration rates (*reduced by grade, vegetation, etc.*) 3. [Bio-]degradation of landfill wastes: • Degradation time-frame (*rapid versus extended time*) • Effects and duration on chemistry (*oxidation-reduction [redox], carbonate, CO2, pH, etc.*) 4. Flood events: • 500 year
Processes:	1. Net infiltration: • Under current conditions • During period of active cover maintenance (*incorporating ET as a process*) • Following period of active cover maintenance (*reduced by grade, vegetation, etc.*) 2. Ingrowth of radium from uranium and thorium decay: 3. Partitioning of radium, uranium, thorium from soil to water/landfill leachate: • Decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 4. Transport within the partially-saturated zone: 5. Mixing at the water table: • Depth of penetration, and dilution • Sorption/complexation, mineral dissolution/precipitation 6. Transport within the saturated aquifer: • Advection, dispersion, decay/ingrowth, sorption/complexation, mineral dissolution/precipitation 7. Discharge to, and mixing with, Missouri River: • Hyporheic zone chemical process • Sorption/complexation, mineral dissolution/precipitation

The Uranium Mill Tailings Remediation Program (UMTRA) focused on the design of purpose-built repositories for uranium tailings piles; however, the UMTRA containment design time-frame of 1000 years is a guide for other radionuclide wastes.

One important event is the grading of Areas 1 and 2 and the emplacement of the final landfill cover on top of the current landfill cover material in these areas. This new cover will greatly reduce infiltration and the potential for mass transfer of radionuclides to mobile water for the period of active maintenance. If active maintenance were to cease, over some time the effectiveness of the landfill cover may decline, potentially resulting in an increased infiltration rate. However, infiltration rates following cessation of active cover maintenance would be expected to be lower than under current

Commented [cao27]: See comments 17 and 25

Commented [cao28]: ditto

Commented [cao29]: Does the period of active maintenance here equal 1000Years?

See Board comments that: "However, the package lacked sufficient information on the long term protectiveness of the preferred remedy. Specifically, how the preferred remedy remains protective given the increasing daughter ingrowth concentrations of radium 226/228, radon 222, and the increase in toxicity over time (1000 years).

Both of these landfill designs (Subtitle D and UMTRCA), as in the preferred alternative, have shortcomings for RIM waste itself and especially in a humid region. A comparison of various landfill capping designs addressing both humid region conditions and long term protection from RIM (1000 years) would be an important concept for the preferred remedy. However, the package did not appear to include alternative cap designs, i.e., EPA landfill cap guidance design, existing cap designs for similar RIM at Weldon Springs, or evapotranspiration cover cap system designs (OSWER Fact Sheets: EPA 5420F-03-015, 2003; EPA 542-F11-001, 2011). For example; a Subtitled C/UMTRCA hybrid may be suitable for both long term infiltration management and radiation shielding protection, The Board recommends that the region include in its remedy selection process evaluations of cap designs similar, but not limited to, the above conditions and guidances. The package also does not address several aspects of the potential for future migration of contamination to ground water. The current lack of a discernable plume above MCL levels may not be a sufficient basis to determine there is little or no potential for there ever to be one. Particularly in light of the long-lived toxic nature of the radioactive contaminants as well as chemical and physical changes over time at the landfill, the Board recommends that a more rigorous evaluation of potential migration to groundwater be undertaken. The evaluation should not assume that pumping at the former active sanitary landfill will continue, unless that is part of this remedy. For these reasons, the Board recommends that the region provide further information on alternative cap designs plus fate and transport of groundwater that supports the preferred remedy's long term protectiveness.

conditions since the cover design incorporates a grade (whereas, the majority of the current landfill cover is flat) and other features that would endure for many years following cessation of active maintenance.

Another important event is the slowing rate of biodegradation of organic materials in the landfill over time; this will alter the geochemistry within the landfill wastes and impact radionuclide partitioning between mobile and immobile phases in the refuse that contains RIM, the underlying refuse that does not contain RIM, and potentially the underlying alluvial aquifer.

Primary Site-Specific Processes

Several processes may affect the potential for radionuclide partitioning and migration, and the potential for radionuclide transport within the partially saturated and saturated zones at the Site. Example processes are summarized in Table 1. One important process is the complex interaction of the RIM with the surrounding pore water, and the role of pore water and soil chemistry on the potential for radionuclide partitioning and migration. Since radionuclide geochemistry will be an important process in the modeling scenarios, an overview of relevant radionuclide geochemistry is provided below.

Geochemistry of Radionuclide Decay, Ingrowth, Partitioning and Migration

Radium Geochemistry

Radium dominantly occurs within leached barium sulfate residues that were mixed with soil ~~and used as daily and intermediate soil cover for solid waste disposed at~~ Areas 1 and 2. The co-precipitation of radium into barium sulfate is a well known process to control radium (Doerner and Hoskins, 1925; Bruno et al., 2007; Zhu 2004a, 2004b; Mahoney 1998, 2001; Grandia et al., 2008; Bosbach et al., 2010). Consequently, equilibrium between pore water and the radium component of barium sulfate will define the initial radium source term leached from the RIM.

Radium may also be attenuated in clean alluvium and groundwater via adsorption onto iron-bearing minerals, ion exchange on clays, and co-precipitation with other sulfate and carbonate minerals such as gypsum and calcite. Of these mechanisms, co-precipitation is expected to be the dominant process close to the landfill due to the sandy nature of the aquifer and expectedly low redox conditions (making iron oxyhydroxides unstable). Downgradient of the landfill - and increasingly within the landfill over time - more oxidizing conditions may be present, and the abundance of iron-bearing minerals available for radium adsorption may increase. Another important consequence of the change in landfill biogeochemistry over time is the likely increase in pH as readily-biodegradable material is consumed. As pH increases, the amount of calcite that will precipitate will increase, and radium co-precipitation with calcite will be more favored, reducing its mobility.

Uranium Geochemistry

Uranium and thorium are important because they occur within the RIM and they decay over time, producing additional radium. Under current conditions uranium concentrations are expected to be controlled by uraninite (UO_2) due to the reducing conditions within the landfill. If oxidizing conditions

Commented [cao30]: How does this take into account the ingrowth issue (the RIM will getter hotter over time) that the Board identified/discussed during review meeting and in spring 2012 draft recommendations?

Commented [cao31]: How much of this is there – see comment 3 above, where Board discussed various documents in the administrative record indicating that "Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results."

Commented [cao32]: See above comments (e.g., #3)

Commented [cao33]: Is this expectation discussed/supported in the administrative record (FS? SFS?)

Commented [cao34]: ditto

Commented [cao35]: see comment 31

Commented [cao36]: In light of Board's spring 2012 draft recommendations/comments (see #18 and #22 above), is the "likely increase" here explained in the FS or SFS?

Commented [cao37]: See comment 33 above

Commented [cao38]: Is this expectation affected by Board's spring 2012 draft recommendations/comments?

return, however, then uranium solubility could be controlled by the generally more soluble U^{+6} (uranyl) minerals such as schoepite [$UO_2(OH)_2 \cdot 2H_2O$] or less soluble forms such as carnotite (KUO_2VO_4) and tyuyamunite [$Ca(UO_2)_2(VO_4)_2$] (Tokunaga et al., 2009). In addition to the oxidation state of uranium, other factors affecting dissolved concentrations include levels of dissolved carbonate generated by biodegradation (which increase solubility) and presence of iron oxyhydroxides (which decrease solubility).

Thorium Geochemistry

Thorium is not redox sensitive and solubility conditions will be controlled by thorianite (ThO_2) under all redox conditions. Complexation reactions that form thorium carbonate complexes are not as significant as those for uranyl carbonate complexes, but they will play a role in thorianite solubility calculations. Reductions in carbon dioxide pressures will also reduce thorium concentrations in groundwater.

The long-term in-growth of ^{226}Ra from ^{230}Th is complicated by the fact that the majority of in-growth radium will be retained within the crystal structure of the thorianite (ThO_2). Only a small fraction of the radium that is produced from the decay of thorium will have the potential to be released to groundwater. This fraction is expected to be derived from near the surface of the thorianite crystals.

Commented [cao39]: See comments 30 – 38 on previous page – in light of Board's spring 2012 draft recommendations/comments, is this conclusion specifically discussed/supported in the FS or SFS?

Calculation Approach

General

The approach to undertaking modeling calculations will follow the sequence of steps defined below:

- Determine and document final FEPs;
- Identify simulation scenarios, based on the final FEPs;
- Identify parameter ranges and uncertainties;
- Develop necessary model(s);
- Complete model calculations; and
- Present and interpret results.

As the modeling is implemented, there will be some iteration between steps in the sequence. It is expected that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. It is envisioned that communication and interaction will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables for review and discussion.

Graded Approach

A graded approach is proposed to undertake the modeling analyses (USEPA 2002, 2009). This graded approach will:

- Use relatively simple methods for initial calculations under the premise that the inherent conservatisms are protective of groundwater and other receptors. Increasing simulation rigor will only be used, if necessary, if simpler approach(es) yield unreasonable results.
- Provide a mechanism to cease model calculations if it becomes evident that no further calculations are necessary. For example, saturated zone flow and transport calculations will only be undertaken if geochemical and vadose zone modeling calculations suggest that a potentially measurable impact to groundwater could occur.

The modeling approach and specific model calculations will be designed to incorporate the principal FEPs while mitigating the potential for computationally-intensive calculations that prevent a thorough exploration of parameter variability and scenario uncertainty. Multiple scenarios will be simulated to evaluate the potential impact of scenario uncertainty on model outcomes, while sensitivity analysis will be used to evaluate the potential impact of parameter variability on model outcomes.

Modeling analyses will be designed to predict the concentration of radium in groundwater for a period of 1,000 years. Concentrations will be forecast at defined compliance locations including, but not limited to, the property fence line/boundary, for the 1,000-year period and will be compared to regulatory standards. If regulatory standards are not exceeded then no further analyses will be required. However, if simulated concentrations exceed regulatory standards, the graded approach will be used to identify the technical element of the modeling approach that incurs the most inherent conservatism in the calculations so that element of the modeling approach can be treated more rigorously to reduce that inherent conservatism (Dixon et al, 2008). If the graded simulation approach has been applied until all inherent conservatisms have been reduced or eliminated, yet simulated concentrations exceed regulatory standards, then this will be considered to be a reliable result.

Commented [cao40]: The administrative record already includes well samples that show MCLs are exceeded. See comment 15 above.

Simulation Code Selection

Table 1 outlines primary events and processes that will be considered in the calculations. The range of potential outcomes will be evaluated by performing several model simulations that consider reasonable alternate conceptualizations of subsurface conditions. Since parameterization of the geochemical component of the model is likely subject to more variability and uncertainty than the groundwater flow component of the model - given the large number of chemical processes that potentially affect radium fate and transport – advective-dispersive migration will be simulated as one-dimensional (1-D), coupled with a rigorous treatment of the complex geochemical processes. The following sequential series of calculations is proposed to collectively comprise the model [consistent with the graded approach, some calculations will only be undertaken if necessary based on the results of preceding calculations]:

1. The Hydrologic Evaluation of Landfill Performance (HELP) code will be used to determine the run-off component of the surface-water balance and remaining water available for infiltration through cover materials under current conditions, final cover conditions, and following the period of active cover maintenance;
2. HYDRUS 1-D (Simunek et al., 1998) will be used to simulate the water balance in the subsurface (after run-off has been accounted for) and the migration of infiltrating water;
3. The USGS-supported geochemical simulation software, PHREEQC (Parkhurst and Appelo, 1999), which is linked to HYDRUS through the HP1 program (Jacques and Simunek, 2005), will be executed simultaneously to provide concentrations of radionuclides in the leachate as it moves within the unsaturated refuse and underlying unsaturated alluvium;
4. The depth of penetration of any leachate that reaches the water table will be calculated using an established method such as that detailed by USEPA (1996);
5. PHREEQC, linked with HYDRUS, will then be used to calculate the effects of mixing on geochemistry that occurs between the leachate and groundwater at the water table;
6. Output from these calculations will provide the time-varying groundwater composition for simulating 1-D radionuclide fate and transport within the saturated zone toward the Missouri River using PHREEQC; and
7. PHREEQC will be used to represent geochemical processes that may occur within the hyporheic zone of the Missouri River.

Commented [cao41]: See comments above (e.g., #4, #17 etc)

Overview of HELP Calculations

HELP (Schroeder, P.R. et al, 1994a, 1994b; Berger, 2011; Berger and Schroeder, 2012) is a program originally developed by USEPA to evaluate the effectiveness of landfill cover designs. HELP will first be used to estimate the typical, quasi-steady-state surface-water balance, emphasizing the run-off rate and the net water available for infiltration through the current landfill cover. The purpose of these calculations is solely to support validation of the modeling approach and constrain the values of certain parameters to be consistent with historical water samples. HELP will then be used to make similar calculations to estimate run-off and the net water available for infiltration through the new landfill cover that would be constructed under the ROD-selected remedy, and to estimate run-off and the net water available for infiltration through the new cover following the period of active maintenance. Alternate periods of active maintenance may be considered in alternate simulation scenarios. The HELP model can explicitly account for rainfall-runoff under alternate cover designs, including alternate slopes (grades).

Commented [cao42]: See comments above (e.g., #4, #17 etc)

Overview of HYDRUS 1-D Calculations

HYDRUS-1D (Simunek et al., 1998) is a public domain Windows-based modeling environment that simulates the movement of water, heat, and multiple solutes in variably saturated media. The flow equation formulation in HYDRUS incorporates a sink term to account for water uptake by plant roots, as well as a dual-porosity type flow capability in which one fraction of the water content is mobile and another fraction is immobile. The solute transport equations consider advective-dispersive transport in the liquid phase, as well as diffusion in the gaseous phase. HYDRUS 1-D (Simunek et al., 1998) will be

used to simulate the water balance in the subsurface (after run-off has been accounted for), and the migration of infiltrating water.

HYDRUS 1-D is linked to PHREEQC through the HP1 modeling software (Jacques and Simunek, 2005). This allows simulation of complex bio-geochemical reactions. Consistent with the graded modeling approach, the initial simulations will assume that radionuclide attenuation in landfill leachate only occurs in groundwater. However, the HP1 software may be used to estimate attenuation in the non-radiologically impacted refuse and unsaturated alluvium underlying Areas 1 and 2 if unreasonable results are obtained using the more conservative simplifying assumption.

Overview of PHREEQC Calculations

Geochemical modeling will first be completed to estimate the leaching potential of various radionuclides under current site conditions. The purpose of these calculations is to support validation of the groundwater modeling approach and constrain the values of certain parameters to be consistent with historical water samples. Following these calculations, the modeling will be used to evaluate the leaching potential under long-term future conditions under the ROD-selected remedy.

Commented [cao43]: ditto

Geochemical modeling methods to estimate source term concentrations for the radio-isotopes will primarily rely upon equilibrium thermodynamics and will be based upon mineral solubility relationships using current ground water compositions. Calculations will be performed using PHREEQC (Parkhurst and Apello, 1999). Solubility calculations for end member phases will be used for thorium and uranium. Radium will be assumed to be present as a solid-solution in barite with a lower thermodynamic activity. Solubility constants for uranium and thorium will, for the most part, be based upon the OECD NEA compilations (Guillaumont et al., 2003; and Rand et al., 2008). Other data sources will be used as needed (Dong and Brooks, 2006, 2008; Duro et al., 2006; Langmuir, 1978; Tokunaga et al., 2009). The ingrowth of ^{226}Ra from ^{230}Th is a time dependent process and the kinetics capabilities in PHREEQC will be used to estimate the production of ^{226}Ra for a period of 1,000 years.

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1-D transport modeling will also be performed with PHREEQC. Modeling will simulate a chemical system that is sufficiently complex to include the effects of landfill and groundwater geochemistry described above. Site-specific groundwater and soil data for uranium, thorium, and radium will define initial concentrations for these isotopes. The site analytical results, particularly the groundwater analyses, will also provide details on the overall geochemical environment of the landfill. The PHREEQC fate and transport model will include the following features:

- The effect of radium in-growth from the decay of thorium over time;
- Decreased methane generation and a possible change in site redox conditions from the reducing conditions currently present at the site to more oxidizing conditions;
- Radionuclide precipitation and/or co-precipitation, such as the partitioning of radium into calcite (Yoshida et al., 2008) present within the landfill;
- Changes in iron stability and potential precipitation of iron-bearing phases for the adsorption of radionuclides; and

- Adsorption reactions (surface complexation and ion exchange) (Dzombak and Morel, 1990; Mahoney et al. 2009a, b; Rojo, et al., 2008; Pabalan et al., 1998).

<u>Model Validation and Predictive Sensitivity Analysis</u>

Historical groundwater data have exhibited few detections of radionuclides. As such, a rigorous calibration exercise is not warranted or justifiable. However, the historical data will be used to validate the modeling calculations and potentially bound the values of some parameter combinations by simulating current conditions prior to undertaking predictive calculations. Multiple simulations will be conducted to evaluate the range of forecasts of possible impacts on groundwater beneath the landfill, at the property fence line/boundary, within surface water, at any defined receptors, and at any other locations of interest. Multiple scenarios will be simulated and predictive sensitivity analyses will be used to evaluate the potential impact of parameter variability on model outcomes at these locations. Although outside the scope of the proposed modeling task, the results of multiple-scenario and parameter-/prediction-sensitivity analyses can help guide the sampling frequency for long-term monitoring programs by providing a range of possible arrival-times and peak-concentrations for contamination at identified compliance locations such as the property fence line/boundary.

Commented [cao44]: Board noted MCL exceedances and their significance in Superfund program – see comment 15 above

Commented [cao45]: Gist of Board's spring 2012 draft recommendations/comments is that more data/wells are needed – so would so just using historical data address Board's recommendations/concerns?

Deliverables

The final deliverable anticipated to be developed from the modeling effort is a Technical Memorandum documenting the technical approach, assumptions, model development, parameterization, simulated scenarios, and results obtained. However, it is anticipated that there will be communication and interaction with USEPA to seek input on the FEPs, simulation scenarios, and parameter ranges and uncertainties identified for inclusion in the modeling prior to undertaking the model calculations. Communication and interaction with USEPA will include the following:

- Presentation and discussion of certain detailed or fundamental concepts – such as the CSM, FEPs and scenarios for inclusion in the modeling;
- Discussion of other less critical aspects of the modeling task; and
- Presentation of intermediate deliverables to USEPA for review and discussion.

No revisions to the SFS report are expected to be required as a result of this modeling effort.

Commented [cao46]: Is this premature conclusion?

Schedule

It is anticipated that the geochemical evaluation of potential leaching of radionuclides, including preparation and submittal of the Technical Memorandum, will be completed within twelve weeks of the approval to proceed.

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Commented [cao47]: what about EPA's rad and other CERCLA guidance documents?

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The Board's draft recommendations from spring of 2012 included other things that are relevant to this SOW for ground water, including language from the initial draft ("Groundwater: monitoring wells placed in perimeter fashion; dated GW data—gather new data now; wells seem to be clustered—large gaps—need wells in between gaps to determine if there is, in fact, a plume issue (e.g., predesign installation of new wells); if we can't fully characterize GW, then we need to have a sufficient record to substantiate that conclusion"), as well as later versions which said: "Based on the information presented to the Board, it appears that there have been some samples of groundwater at this site that exceed standards considered as ARARs. The Region also stated that no discernable plume at this site has been identified, and its preferred approach is to continue monitoring groundwater. Generally, under existing Agency guidance, exceeding a maximum contaminant level in groundwater normally would warrant a response action (OSWER Directive 9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection* Decisions and OSWER Directive 9283.1-33 *Summary of Key Existing EPA CERCLA Policies for Groundwater* Restoration). The Board recommends that the Region consider additional wells at the site to better delineate the vertical and lateral extent of potential site-related contamination previously indentified from limited sampling in Area 1 and especially Area 2. These additional wells would be instrumental in clarifying the presence of an isolated groundwater hot-spot versus a groundwater plume in the complex subsurface geologic setting. In addition, the Region should explain why there are numerous decommissioned wells on site. Sampling of these wells may have provided a more complete picture of potential groundwater contamination. The general recommendation is that the additional wells be nested along the western border (Crossroad property) of Area 2 in the unconsolidated alluvial deposits and the underlying fractured and vuggy, limestone Keokuk formation. The Board also notes that the Agency's long-standing policy has been that monitoring by itself is not a CERCLA remedial action, and believes that the information submitted to the Board may not support a conclusion that monitoring to evaluate effectiveness of the source control remedy (if that approach is selected) would constitute an effective or final groundwater response action for this site. As such, the Board recommends that the decision documents clearly explain the role of monitoring in the Region's preferred approach, and indicate that any potential groundwater cleanup would be addressed in a separate decision document in the future representing a final ground water remedial action, should one be needed.

In addition, the package at page 22 states that "Only four wells exhibited a total radium concentration above 5 pCi/l. These exceedances ranged from 5.74 pCi/l to 6.33 pCi/l. The slight exceedances are isolated spatially. Two of the four wells with total radium exceedances are located in areas that are not downgradient of either Radiological Area 1 or Radiological Area 2." The chart on page 21, however, indicates that there were two wells with exceedances and that the maximum detected concentration was 8 pCi/l. The Board recommends that the Region reconcile these discrepancies.

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This appears inconsistent with Board's views expressed during meeting and in spring 2012 draft recommendations – for example: "Based on the package provided to the Board, it appears that there are potentially significant amounts of RIM that are highly toxic (e.g., based on NRC estimates in the 1982 and 1988 reports, radium of up to 22,000 pCi/gr, bismuth-214 of up to 19,000 pCi/g, and average thorium-230 concentrations of 9000 pCi/gr; the package at page 44 notes that the RI report discussed thorium-230 at levels as high as 57,300 pCi/gr) and that the highest gamma peak intensity readings are at shallow depths. The FS states (page 84) that most of Area 2 contains RIM at above 100 pCi/gr. The NRC reports also discuss how the toxicity of this RIM will continue to increase over time: "Ra-226 activity will increase in time (for example, over the next 200 years, Ra-226 activity will increase nine-fold over the present level). This increase in Ra-226 must be considered in evaluating the long-term hazard posed by this radioactive material." (1988 NRC report, page 14). The SFS also acknowledges this fact. Thus, based on the data, it appears there is discrete, accessible highly toxic principal threat waste at this site."

Scope of Work and Schedule

Alternative Cover Designs

Introduction

In an October 12, 2012 letter, EPA Region 7 asked that, as part of a Supplement to the Supplemental Feasibility Study [SFS] (EMSI, 2011), the Respondents evaluate potential alternative landfill cover designs including but not limited to an Evapo-Transpiration (ET) Cover for Operable Unit-1 (OU-1) of the West Lake Landfill. EPA had previously indicated that the National Remedy Review Board wanted the use of synthetic cover materials evaluated as part of the Supplemental SFS. This work plan presents a scope of work for evaluation of the potential application of an ET cover and for the potential application of an alternative cover that would incorporate a synthetic material layer, specifically a geosynthetic clay liner (GCL), into the design of the landfill cover for OU-1.

Background

ROD-Selected Remedy Landfill Cover

The remedy selected in EPA's Record of Decision (ROD) for OU-1 (the ROD-selected remedy) includes an enhanced Resource Conservation and Recovery Act (RCRA) Subtitle D (solid waste) cover system to be installed and maintained over Radiological Areas 1 and 2 (EPA, 2008). This cover system would at a minimum be designed to meet the design requirements for final cover systems at municipal solid waste landfills (MSWLF) and the Missouri closure and post-closure requirements for sanitary landfills, with additional enhancements consistent with standards for uranium mill tailings sites (i.e., armoring layer, protection against gamma radiation, and radon barrier). Specifically, the design of the landfill cover under the ROD-selected remedy is anticipated to consist of the following layers (from top to bottom):

- A one-foot thick layer of soil capable of sustaining vegetative growth;
- A two-foot thick infiltration layer of compacted USCS CL, CH, ML, MH, or SC soil-type with a coefficient of permeability of 1×10^{-5} cm/sec or less; and
- A two foot thick bio-intrusion/marker layer consisting of well-graded rock or concrete/asphaltic concrete rubble.

Such a cover system includes a low conductivity barrier layer, in this case the two foot thick infiltration layer described above, to minimize percolation of rainfall or snowmelt through the cover from entering the underlying waste materials.

Evapotranspiration Cover

In contrast, ET cover systems are designed to rely on the ability of the soil layer in the landfill cover to store the precipitation until it is naturally evaporated or transpired by the vegetative cover (EPA, 2011). ET cover systems rely on the appropriate water storage capacity of the soil layer and, in wetter climates, vegetation that can remove percolation rather than relying on an engineered low hydraulic conductivity barrier layer to prevent percolation from entering the underlying waste materials.

As described by EPA (2011), "ET cover systems are generally considered more applicable in areas that have arid or semi-arid climates like those found in parts of the Great Plains and West (e.g., North and South Dakota, Montana, Idaho, eastern Washington and Oregon, Utah, Colorado, West Texas, New Mexico, Arizona, Nevada, and southern California). Albright and Benson (2005) in their examination of data generated in EPA's Alternative Cover Assessment Program (ACAP) found: "In humid locations with the abundant precipitation and typically lower potential evapotranspiration, the store-and-release mechanism used by ET covers does not provide sufficient hydraulic control to match the performance of *conventional composite covers*. (emphasis added) However, the ACAP field data did show that in humid locations properly designed ET covers can provide performance comparable to that of the *compacted clay covers* in those locations" (EPA, 2011).

Review of sites contained in EPA's alternative cover database http://cluin.org/products/altcovers/ indicates that only two alternative cover designs have been documented in Missouri; one is a demonstration project installed in 1995 for an inactive fly ash waste pond at a power plant and the other is an ET cover constructed in 2003 over contaminated soil at a former wood treating plant. In the first case, it was determined that the ET cover did not successfully manage precipitation that fell on the inactive ash pond. No information was available regarding the long term performance of the ET cover installed at the second site listed in the EPA database. No Missouri sanitary landfills with ET covers have been identified.

Landfill Cover Incorporating a Geosynthetic Layer

There are several types of geosynthetic products that are often used in landfill containment design that could be considered for alternate landfill cover designs to the soil-only landfill cover prescribed in the ROD remedy. For example, geomembranes or GCLs are often used as low-permeability components, and geonets and geotextiles are often used as drainage layers. For this evaluation, the use of a GCL will be evaluated. A GCL is a synthetic product composed of a core layer of natural low-permeability bentonite clay sandwiched between geotextile fabric. With its low permeability, a GCL may have the potential to be used as a substitute for all or part of the infiltration layer, and still achieve the objective of minimizing percolation through the cover. Selection of a GCL as the representative process option for the evaluation of an alternative cover using synthetic materials was based on the reliance of GCL on the presence of bentonitic clay for achieving low permeability. Being a natural material, bentonite is expected to offer significant advantages over plastic-only based geomembranes in terms of longevity and durability.

Approach

The potential implementability of alternative landfill cover designs for Areas 1 and 2 will be evaluated in the same manner that the potential applicability of other technologies are evaluated in the SFS. Specifically, an initial technical implementability screening evaluation will be performed to assess the potential applicability of the alternative landfill cover designs. If the initial screening indicates that one or both of the alternative landfill cover designs are potentially applicable to OU-1, these technologies would then be subjected to further evaluation of their potential effectiveness, implementability and cost. During this phase, the anticipated performance of the alternative landfill cover designs would be compared to that of the cover specified in the ROD-selected remedy. If these evaluations indicate that one or both of the alternative landfill cover designs could provide similar effectiveness at minimizing infiltration at comparable cost, then a recommendation for consideration of use of an alternative landfill cover design would be made.

Evapotranspiration Cover Design

The initial screening of the potential implementability of an ET cover will evaluate the thickness of the soil cover that would be required to prevent percolation of precipitation from reaching the underlying waste materials. This evaluation will be based on an assumption that a capillary barrier type ET cover consisting of a surface vegetated with native plants, a fine-grained layer (appropriate thickness to-be - determined by the evaluation) consisting of clay and/or silt soil for storage of infiltration, and a coarse-grained, biointrusion/marker/capillary break layer consisting of two feet of well-graded rock or concrete/asphaltic concrete rubble would be installed over Areas 1 and 2. Modeling of the anticipated infiltration rate would be performed for a variety of thicknesses for the fine-grained layer beginning with a 2-foot thick layer and progressively increasing in thickness with the goal of identifying the required theoretical layer thickness necessary to prevent or minimize infiltration into the underlying waste mass. Modeling of the anticipated cover thickness would be performed using the UNSAT-H model (Fayer, 2000) or HYDRUS-1D (Šimůnek,et al., 2005).

If the technical implementability screening indicates that infiltration of precipitation can be minimized with an ET cover employing a fine-grained layer 5-feet thick or less, then this technology would be considered potentially implementable and would be subjected to further evaluation of its potential effectiveness, implementability and cost. During this phase, the anticipated performance of an ET cover would be compared to that of the cover specified in the ROD-selected remedy. If these evaluations indicate that an ET cover could provide similar effectiveness at minimizing infiltration at comparable cost, then a recommendation for consideration of use of an ET cover would be made.

Geosynthetic Clay Liner Cover Design

An initial technical screening will be performed to assess the potential implementability of an alternative landfill cover design that incorporates a GCL liner into the landfill cover design specified under the ROD-Selected Remedy (hereafter referred to as the "GCL-alternate cover"). Because use of GCLs in cover systems is a generally accepted technology for landfills, the primary focus of this evaluation will be the anticipated design life of a GCL layer relative to the longevity criteria that have previously been identified as potentially relevant and appropriate requirements under the Uranium Mill Tailings Radiation Control Act regulations for the landfill cover. The initial implementability screening evaluation will also consider site-specific factors that could affect the implementability of a GCL-alternate cover. Specifically, the potential effects of a GCL-alternate cover on the overall stability of the final landfill slopes will be evaluated. In addition, the need for inclusion of additional soil material to allow for installation and incorporation of a GCL in the landfill cover and the resultant approximate impacts on the extent and volume of waste material that would need to be regraded will be considered. Finally, other installation and maintenance issues that may arise will be addressed.

If the initial technology screening evaluation indicates that a GCL-alternate cover is considered potentially implementable, this technology will be subjected to evaluation of its potential effectiveness, implementability and cost. During this phase, the anticipated performance of a GCL-alternate cover would be qualitatively compared to that of the cover specified in the ROD-selected remedy. If these evaluations indicate that a GCL-alternate cover could provide similar effectiveness to the ROD-selected remedy at minimizing infiltration at comparable cost without significant adverse impacts, then a recommendation for consideration of incorporation of a GCL-alternate landfill cover instead of the cover specified in the ROD would be made.

Deliverables

1. Interim Deliverable – A brief memorandum will be prepared summarizing the results of the initial screening of the potential implementability of an ET cover and GCL-alternate cover for OU-1. If an ET cover or GCL alternate cover are considered potentially implementable, this memorandum would also include an evaluation of the potential effectiveness, implementability and cost of these covers. If the results of these evaluations indicate that an ET cover and/or a GCL-alternate cover could provide comparable performance at a comparable cost to that of the low permeability cover included in the ROD-selected remedy, a recommendation for development and evaluation of use of an alternative cover design(s) consisting of ET cover and/or GCL-alternate cover as an alternative(s) to the ROD-selected remedy cover system would also be included in this memorandum.

2. SFS revisions – Assuming that the evaluation of ET cover and/or GCL alternate cover technology only entails evaluation of the potential applicability of this technology and does not result in development of new/additional remedial alternatives, the following revisions to the SFS report are anticipated:

    a. Section 4 – Technology Screening to include evaluation of ET and GCL cover technology implementability

        i. Section 4.2 – Identify ET covers and GCL-alternate covers as additional technologies/process options to be evaluated in the SFS

ii. Section 4.3 – Include a description of ET cover and GCL-alternate cover technologies
iii. Section 4.4 – either
    1. Identify ET cover and/or GCL-alternate cover technology as technologies that were screened out based on implementability factors, or
    2. Evaluate the implementability of ET cover and/or GCL-alternate cover technologies
iv. Figure 24 – Add evaluation of the technical implementability of ET cover and/or GCL-alternate cover technologies to this figure.
v. Figure 27 – Add evaluation of the anticipated effectiveness, implementability and cost of ET cover technology and/or GCL-alternate cover technology.

In the event that ET cover technology and/or GCL-alternate cover technology are found to be potentially applicable based on the site and waste conditions, there may be a need to develop one or more additional remedial alternatives for detailed analysis in the Supplemental SFS report. Such an effort is not included with the scope of the evaluation of alternative landfill cover designs addressed by this Scope of Work.

Schedule

It is anticipated that performance of an initial technology screening of the potential implementability of ET cover and GCL-alternate cover technologies for OU-1 will take approximately six weeks from receipt of EPA approval of this Work Plan. Assuming that an ET cover technology and/or a GCL-alternate cover technology are potentially implementable for OU-1, the technical evaluation of the potential effectiveness, implementability, and cost of such alternative landfill cover designs and preparation of a summary memorandum will take approximately another six weeks time.

Preparation of a Supplemental SFS report that includes the results of the evaluations of ET cover and GCL-alternate cover technologies will be performed once EPA comments on the interim deliverable are received and in conjunction with revisions to the existing SFS report required to address the results of the various other additional tasks EPA has requested.

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Scope of Work and Schedule

Evaluation of the Use of Apatite/Phosphate Treatment Technologies

Introduction

EPA's October 12, 2012 letter indicated that the National Remedy Review Board recommended that more detailed evaluations of potential treatment technologies be conducted as part of a Supplement to the Supplemental Feasibility Study [SFS] (EMSI, 2011). Consequently, EPA has asked the Respondents to evaluate the potential application of apatite and/or phosphate solutions for possible treatment of waste materials and/or groundwater. EPA requested that this evaluation be performed at a level of detail comparable to that used to evaluate the treatment technologies previously analyzed in the SFS.

Approach

Typically, the first step in the identification of potentially applicable remedial technologies is to evaluate general response actions that, based on site conditions and media of concern, could address the remedial action objectives (RAOs) at a site. The RAOs developed for OU-1 did not include direct treatment of the waste materials or treatment of groundwater. Consequently, potential remedial technologies related to these response actions were not evaluated in the FS (EMSI, 2006) or the SFS (EMSI, 2011). For purposes of conducting an evaluation of potential apatite treatment technologies, this initial step, evaluation of general response actions based on site conditions and media of concern, will be skipped. Instead, to comply with EPA's direction, the evaluation will be based on a hypothetical scenario where treatment of the waste materials and/or treatment of groundwater have been deemed appropriate response actions relative to the site conditions and media of concern. In the event that apatite treatment technology is determined to potentially be applicable to OU-1, it may be necessary to revisit the evaluation of general response actions and the identification of other potentially applicable remedial technologies.

Evaluation of the potential applicability of apatite or other phosphate-based treatment technologies will be performed using the same approach used to evaluate other potential remedial technologies under a Feasibility Study level-of-effort. The first step will be to identify potential apatite/phosphate-based treatment technologies and perform an initial screening of the technical implementability of such technologies relative to the waste and site conditions. The anticipated approach to the evaluation of potential application of apatite treatment technology will be based on the following:

1. Review of available published literature; and
2. Discussions with DOE individuals with knowledge of the use and applicability of apatite injection technology.

Subject to results of the initial evaluations, possible applications of apatite/phosphate-based technologies to West Lake Landfill OU-1 may include the following:

1. Injection into waste materials to reduce leaching of radionuclides; and/or
2. Use for treatment of radionuclide occurrences in groundwater.

If the initial evaluations of potential apatite/phosphate-based treatment technologies indicate that such technologies may potentially be applicable to the site and waste conditions in OU-1, these technologies will be subjected to further evaluations including evaluations of potential effectiveness, implementability and cost in accordance with the procedures prescribed in EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988).

Results of Preliminary Evaluations

This section provides a summary of the results of initial evaluations completed prior to and during development of this scope of work. An initial search of technical literature (see References section below) and initial discussions with DOE personnel familiar with use of apatite-based technologies indicate the following:

1. Injection of apatite solution has been successful in halting migration of strontium-90 in groundwater at Hanford;

2. Bench-scale testing at Oak Ridge has indicated that apatite may be effective in treating uranium and heavy metals in groundwater (this reportedly was to be followed up by a pilot-scale test but reports of the results of the pilot-scale testing, if performed, have not yet been located);

3. No reports or information have yet been identified relative to the use of apatite to treat waste/source materials or relative to possible source treatment within a solid waste matrix; and

4. DOE representatives indicated that owing to the potential disruption in chemical equilibrium within the waste matrix, such an application could result in an increase in leaching potential of radionuclides instead of a reduction in leaching potential that would be intended by such an application.

Due to the lack of application of this technology for source stabilization, and in particular the complete lack of application to a source material composed of municipal solid waste, significant uncertainty exists relative to the potential applicability, effectiveness and possible unintended consequences of using apatite technology to attempt to reduce potential leaching of radionuclides from OU-1.

All published information identified to date relates to treatment of select radionuclides and heavy metals in groundwater. Specifically, the only published information located so far relative to treatment of groundwater relates to treatment of strontium, uranium and heavy metals. No information exists regarding the potential use of apatite for treatment of radium or thorium.

Furthermore, EPA previously determined that there is no unacceptable risk of groundwater contamination at the site. Specifically, the ROD contains the following conclusions:

1. *These* (groundwater sampling) *results are not indicative of on-site contaminant plumes, radial migration, or other forms of contiguous groundwater contamination that might be attributable to the landfill units being investigated.* (ROD at p. 20)

2. *The groundwater results show no evidence of significant leaching and migration of radionuclides from Areas 1 and 2.* (ROD at p. 21)

3. *Significant leaching and migration of radionuclides to perched water or groundwater have not occurred despite landfilled waste materials having been exposed to worst-case leaching conditions from surface water infiltration over a period of decades.* (ROD at p. 21)

4. *The lack of radionuclide contamination in groundwater at the Site is consistent with the relatively low solubility of most radionuclides in water and their affinity to adsorb onto the soil matrix.* (ROD at p. 21)

5. *This pathway for migration* (groundwater flow to the river) *is not considered significant under current conditions because the on-site impact to groundwater from the landfill units is so limited.* (ROD at p. 21)

6. *The fourth* (remedial action) *objective* (Collect and treat contaminated groundwater and leachate to contain any contaminant plume and prevent further migration from the source area) *is not applicable because a plume of contaminated groundwater beneath or downgradient of the disposal areas has not been identified.* (ROD at p. 30)

Consequently, groundwater was not determined to be a media of concern (i.e., no plume of groundwater contamination exists) and treatment of groundwater was not identified as a potential response action for the site in the prior FS or SFS. Accordingly, groundwater treatment technologies were not evaluated in either the FS or SFS. If apatite technology were to be evaluated as a remedial alternative, it may be appropriate to also evaluate other possible groundwater treatment technologies.

Alternatively, apatite injection technology could be evaluated as a possible contingent action in the event that groundwater contamination occurs in the future. Again, if apatite technology were to be evaluated as a possible contingent action, there may be a need to evaluate other possible groundwater treatment technologies for use as possible contingent actions.

Deliverables

1. Interim Deliverable – A brief memorandum will be prepared summarizing the results of the evaluation of potential applicability of apatite/phosphate-based treatment technologies to the waste materials and site conditions associated with OU-1. This interim deliverable will also include a recommendation relative to identification and evaluation of potential additional remedial alternatives that may be based on apatite treatment technologies.

2. SFS revisions – Assuming that the evaluation of apatite treatment technologies only entails evaluation of the potential applicability of this technology and does not result in development of new/additional remedial alternatives, the following revisions to the SFS report are anticipated:

    a. Section 4 – Technology Screening to include evaluation of apatite treatment technology
        i. Section 4.2 – identify apatite treatment technology as an additional technology to be evaluated in the SFS
            1. Note: May need to identify other possible groundwater treatment technologies and expand the SFS to include evaluation of these
        ii. Section 4.3 – include a description of apatite injection technology
        iii. Section 4.4 – either:
            1. Identify apatite treatment technology as a technology that was screened out; or
            2. Evaluate the implementability of apatite treatment technology for either:
                a. Chemical stabilization of radionuclides in the waste mass (subject to determining that information exists on possible use of apatite in this manner); or
                b. For use as possible contingent action in the event that groundwater contamination occurs in the future.
        iv. Figure 24 – Add evaluation of the technical implementability of apatite treatment technology(ies) to this figure.
        v. Figure 27 – Add evaluation of the anticipated effectiveness, implementability and cost of apatite treatment technology(ies).

In the event that apatite treatment technology is found to be potentially applicable based on the site and waste conditions, there may be a need to develop one or more additional remedial alternatives for detailed analysis in the Supplemental SFS report. Such an effort is not included with the scope of the evaluation of apatite treatment technology addressed by this Scope of Work.

Clarifications by EPA

EMSI requests clarification from EPA regarding EPA's expectations relative to potential application of apatite and/or phosphate treatment technologies at the site. To date, review of the technical literature and information from other sites has only resulted in identification of application of apatite/phosphate technology for treatment of groundwater. EMSI has not identified any technical literature discussing potential application of apatite and/or phosphate solutions as methods of treating waste/source materials. Therefore, EMSI requests any information EPA can provide regarding known or potential applications of such technologies for direct treatment of waste.

EMSI wastes to discuss with EPA the possible role of apatite or other groundwater treatment technologies relative to preparation of a Supplemental SFS report. These include the following:

1. How the SFS should address the lack of/minimal nature of impacts to groundwater relative to any evaluation of potential apatite treatment technology for groundwater given that:
    a. Groundwater was not identified as a media of concern in the FS or SFS and therefore general response actions and remedial technologies for groundwater were not identified or evaluated in either document.
    b. Groundwater treatment was not identified as being necessary (see above language from the ROD).

2. Evaluation of apatite treatment as a possible contingent technology
    a. Apatite technology could be evaluated as a technology for possible use as a contingent action in the event that significant groundwater impacts arise in the future.
    b. Would there be a need to evaluate other possible technologies that could possibly be used as contingent technologies in the event of future groundwater impacts?

3. Evaluation of apatite treatment (or other contingent groundwater technologies) would be limited to identification and screening of technologies for possible future contingent applications. This would not result in development or evaluation of a remedial alternative(s) for groundwater treatment.

4. Overall evaluation of apatite treatment of groundwater is inconsistent with the FS guidance. Specifically, as groundwater was not identified as a media of concern, the FS and SFS did not identify, screen or evaluate technologies for groundwater treatment.

5. Obtain additional information that EPA may be aware of on prior applications and experience with apatite treatment technology.

Schedule

It is anticipated that collecting available information on potential use of apatite/phosphate-based treatment technologies, screening of the potential implementability of such technologies to the waste materials and site conditions at OU-1, evaluating the potential effectiveness, implementability, and cost of such potential applications, if appropriate, and preparing a summary memorandum will take approximately six weeks after receipt of EPA clarifications to the items identified above.

Preparation of a Supplemental SFS report that includes the results of the evaluations of apatite/phosphate-based treatment technologies will be performed once EPA comments on the interim deliverable are received and in conjunction with revisions to the existing SFS report required to address the results of the various other additional tasks EPA has requested.

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Work Plan

Additional Present Value Cost Estimates

Introduction

The present value (also referred to as present worth) cost estimates presented in the Supplemental Feasibility Study [SFS] (EMSI, 2011) were based on the Office of Management and Budget (OMB) real discount rate of 2.3% (as of 12-2011). EPA's October 12, 2012 letter indicated that the National Remedy Review Board has recommended that present value calculations be performed using a 7% discount rate.

For reference, EPA guidance directs evaluation of alternatives using a 7% discount rate (NCP, OSWER Directives 9355.3-20 and 9355.0-75) for non-federally financed projects. EPA guidance allows for use of lower or higher discount rate than 7% for the FS present value analysis. EPA guidance also requires evaluation of alternatives for federally funded projects to be based on real discount rates found in OMB Circular A-94 (2.3% for 2011).

Approach

Pursuant to EPA's request, present value cost estimate calculations will be prepared based on both the current OMB rate and a 7% discount rate. Accordingly, the cost estimates presented in the SFS will be updated to include both discount rates as will any additional estimates to be developed in conjunction with additional evaluations requested by EPA for a Supplemental SFS. The results of these additional estimates will be compared to previous estimates to determine the sensitivity of the cost estimates to the discount rate.

A narrative will also be prepared to explain why both rates are being used for the SFS. The narrative will present a discussion addressing why use of the OMB rate is more appropriate for the SFS based on the following factors:

1. Remedial action for West Lake Landfill OU-1 will be federally-funded (DOE) in part;
2. Fiscally-constrained approaches were identified to address possible Federal (Superfund) funding of the remedial actions; and
3. The likelihood of being able to obtain a 7% pre-tax return over the anticipated near-term period of remedy construction is remote.

Deliverables

Interim Deliverable – A brief memorandum will be prepared to present the present value cost estimates for the ROD-selected remedy and the two "complete rad removal" alternatives presented in the SFS based on the OMB rate included in the SFS and a 7% discount rate. Development of cost estimates to be performed in conjunction with the other additional evaluations requested by EPA will also include both the OMB rate and a 7% discount rate.

SFS revisions – the following revisions to the SFS report are anticipated as part of this additional evaluation:

1. Section 6.1.7.3 – Revise text to address use of both 7% discount rate and OMB rate
2. Sections 6.2.1.7, 6.2.2.7, and 6.2.3.7 – Revise the discussion of the present value costs of the alternatives to include both present values based on 7% and OMB discount rates
3. Section 7.2.5 – Revise discussion of present values to include values based on both 7% and OMB discount rates
4. Appendix K – Include present value calculations based on both 7% and OMB discount rates

Please note that at the time the Supplemental SFS is prepared, the present value cost estimates will be updated to reflect the then-current OMB rate, which may differ from the rate used in the SFS or in preparation of the various interim deliverables documenting the results of the additional evaluations requested by EPA.

Clarifications by EPA

No additional clarification is being requested from EPA at this time.

Schedule

Preparation of additional present value cost estimates for the ROD-selected remedy and the two "complete rad removal" alternatives and preparation of a brief summary memorandum of the results of these additional evaluations will take approximately three weeks. Preparation of present value costs associated with the other additional evaluations requested by EPA will be completed in accordance with the schedules for completion of these other evaluations.

Preparation of present value costs using both discount rates for the other evaluations requested by EPA will be performed once EPA comments on the interim deliverables, and in conjunction with preparation of a Supplemental SFS.

References

Engineering Management Support, Inc. (EMSI), 2011, Supplemental Feasibility Study, Radiologically-Impacted Material Excavation Alternative Analysis, West Lake Landfill Operable Unit-1, December 16.

United States Environmental Protection Agency (EPA), 2000, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, EPA 540-R-00-002/OSWER Directive 9355.0-75, July.

EPA, 1993, Memorandum: Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis, OSWER Directive No. 9355.3-20, June 25.

Work Plan
Partial Excavation Alternative

Introduction

In an October 12, 2012 letter to the West Lake Landfill Operable Unit-1 (OU-1) Respondents ("EPA's Letter"), EPA directed Respondents to update the analysis of the alternative presented in the May 2006 Feasibility Study for OU-1 (EMSI, 2006) ("FS") involving excavation of material with higher levels of radioactivity ("FS Partial Excavation Alternative"). EPA's Letter requested that the updated analysis be at a level of detail comparable to the alternatives already analyzed in the Supplemental Feasibility Study (SFS) for West Lake Landfill Operable Unit-1 (EMSI, 2011). To implement this directive, Respondents therefore need to use the same criteria that were used to define the FS Partial Excavation Alternative to define the scope of the Partial Excavation with Off-Site Disposal Alternative and Partial Excavation with On-Site Alternative requested in EPA's Letter ("Partial Excavation Alternatives") -- that is, the presence of radionuclides with activity levels greater than 1,000 picocuries per gram pCi/g or the presence of downhole gamma readings greater than 500,000 counts per minute (cpm).

Approach

The detailed evaluation of the Partial Excavation Alternatives will be prepared in a similar manner and level of detail as was used for the evaluation of the ROD-selected remedy and the two "complete rad removal alternatives", as presented in the SFS. Specifically, excavation and final grading plans will be prepared for the Partial Excavation Alternatives based on the criteria listed above. The volumes of overburden and radiologically-impacted material (RIM) that would be excavated under these alternatives will be calculated. The thickness of cover material necessary to provide protection against gamma radiation and radon emissions under the Partial Excavation Alternatives will be calculated using the same approach as was used in the SFS for evaluation of the cover thickness for the ROD-selected remedy. A construction schedule and cost estimate will be developed for the Partial Excavation Alternatives at a similar level of detail and based on similar assumptions and factors as were used to develop the schedules and cost estimates presented in the SFS. Calculations of the residual long-term risk that may remain under the Partial Excavation Alternatives as well as calculations of potential short-term risks to workers and the public will be performed in a manner similar to that used in the SFS.

Deliverables

Interim Deliverable –A technical memorandum will be prepared that presents the following information relative to the Partial Excavation Alternatives:

1. Definition of and basis for the overall scope of the Partial Excavation Alternatives;

2. Excavation and final grading plans;
3. Cover thickness calculations;
4. Short-term and long-term risk calculations;
5. Construction schedule (for both fiscally and non-fiscally constrained approaches);
6. Construction cost estimates (for both fiscally and non-fiscally constrained approaches); and
7. Present value analysis (for both fiscally and non-fiscally constrained approaches).

SFS Revisions – The existing SFS text, tables and appendices will be amended to include the results of Partial Excavation Alternatives development and evaluation. Subject to EPA comments on the Interim Deliverable, the following specific revisions to the December 2011 SFS report are anticipated:

1. New SFS Sections would include:
    a. Section 5.4 describing the Partial Excavation Alternatives
    b. 6.2.4 presenting the detailed evaluation of the Partial Excavation Alternative with Off-Site Disposal
    c. Section 6.2.5 presenting the detailed evaluation of the Partial Excavation Alternative with On-Site Disposal
    d. New Appendix or New Sub-Appendices to Appendix B to present the evaluation of the volumes of RIM to be excavated under the Partial Excavation Alternatives
2. Sections of the SFS that would need to be amended include:
    a. Section 7 – Comparative Analysis
    b. Appendix F – Calculate the required cover thickness associated with the Partial Excavation Alternatives
    c. Appendix H – Estimate the potential risks to the community and workers based on the volumes of RIM and overburden material to be excavated and revised construction schedules under the Partial Excavation Alternatives
    d. Appendix I – Prepare additional estimates of Greenhouse Gas Emissions associated with the Partial Excavation Alternatives
    e. Appendix J – Prepare additional construction schedules for the Partial Excavation Alternatives
    f. Appendix J – Prepare additional estimates of the construction costs (both fiscally constrained and not-fiscally constrained) for the Partial Excavation Alternatives

Schedule

Upon receipt of EPA approval of this Work Plan, it is anticipated that evaluation of the Partial Excavation Alternatives and preparation of an Interim Technical Memorandum will require approximately four months.

Preparation of a Supplemental SFS report that includes the results of the evaluations of the Partial Excavation Alternatives will be performed once EPA comments on the interim deliverable are received and in conjunction with revisions to the existing SFS report required to address the results of the various other additional tasks EPA has requested.

References

Engineering Management Support, Inc. (EMSI), 2011, Supplemental Feasibility Study, Radiologically-Impacted Material Excavation Alternative Analysis, West Lake Landfill Operable Unit-1, December 16.

EMSI, 2006, Feasibility Study, West Lake Landfill Operable Unit-1, May 8.

Work Plan

Alternative Area 2 Excavation Depths and Volumes

Introduction

EPA's October 12, 2012 letter to the West Lake Landfill Operable Unit 1 (OU-1) Respondents states that, during an early consultation with the National Remedy Review Board (NRRB), the NRRB indicated that the deeper radiological detections in borings WL-210 and WL-235 are unreliable. Consequently, EPA has asked that the volume of radiologically-impacted material (RIM) considered for possible excavation under the "complete rad removal" alternatives be revised to exclude deeper intervals in soil borings WL-210 and WL-235 in Area 2.

Evaluation of the soil sample analytical results and the downhole gamma logging data during preparation of the SFS indicated that soil containing radionuclides above the levels used to identify material to be included within the scope of the two "complete rad removal" alternatives was potentially present within a deeper depth interval beneath the southwestern portion of Area 2. Specifically, elevated gamma peaks were identified on the downhole gamma logs at depths of 47.5 feet (ft) below ground surface (bgs) in WL-210 and 22.5 ft bgs in WL-235; however, the Remedial Investigation (RI) [EMSI, 2000] states (on p. 97) that boring WL-210 was re-logged because during the first logging attempt, material was knocked into the hole and that the presence of this material may have been the cause of a small poorly defined peak at the bottom of this boring. The RI also states (again on p. 97) that the presence of a poorly defined peak at the bottom of WL-235 may also be the result of RIM at shallow depths having been knocked into this borehole during drilling or logging activities.

Although the RI raised possible questions about the representativeness of the downhole gamma logs for the deeper intervals of these two borings, a soil sample obtained from boring WL-210 detected the presence of total Thorium-230+232 at a depth of 40 ft bgs at a level (18.6 pCi/g) above the cleanup level (7.9 pCi/g) used to evaluate potential excavation alternatives. A duplicate sample obtained from this same depth interval contained total thorium at 11.6 pCi/g. These samples were obtained from a depth of 40 ft, 10 feet above the bottom of the borehole. In addition, these samples were obtained during drilling of the borehole, prior to the downhole logging activities that may have resulted in surficial material being knocked into the hole. Therefore, these sample results likely represent actual conditions at the 40 ft depth interval in boring WL-210. The RI sampling did not include collection of a soil sample from the deeper portion of the WL-235.

Although uncertainty exists regarding the representativeness of the downhole gamma logs at these two locations, the soil sample result from the 40 ft depth in WL-210 combined with the downhole gamma logs were used to define an area and volume of a deeper interval of RIM occurrence beneath the southwestern portion of Area 2. This material and the associated overburden material that would need to be removed to allow for excavation of this RIM, were included within the overall volumes of materials that would need to be excavated if one of the "complete rad removal" alternatives were to be implemented at the site. (Note: Deeper intervals of radiologically-impacted material were also identified beneath other portions of Area 2 but are not the subject of this re-evaluation).

Because of the uncertainty associated with the downhole gamma logging at these two locations, EPA has indicated that the NRRB believes the radiological detections in the deeper portions of these two borings are unreliable. EPA has therefore requested that the volumes of materials that may be removed under a "complete rad removal" alternative be re-estimated to exclude the deeper depth intervals in borings WL-210 and WL-235.

Approach

The following approach will be used to develop a revised excavation volume for Area 2:

1. Revise the calculated volume of material to be excavated under the "complete rad removal" alternatives to eliminate deeper intervals in soil borings WL-210 and WL-235 and consequently to eliminate removal of the deeper interval of RIM material from the southwestern portion of Area 2; and

2. Develop revised estimates of the potential risks to workers and the public, revised projected construction schedules, and revised cost estimates for excavation and offsite or onsite disposal based on exclusion of the potential deeper occurrences of RIM beneath the southwestern portion of Area 2.

Deliverables

The following deliverables will be prepared pursuant to this task

1. Interim Deliverable – A brief memorandum will be prepared summarizing the revisions to the RIM extent and volumes resulting from exclusion of the deeper interval beneath the southwestern portion of Area 2. If the re-evaluation of the volume material results in significant changes in the amounts of materials that would be excavated under the "complete rad removal" alternatives, this memorandum will also include evaluations of potential risks, revised calculations of greenhouse gas emissions, revised anticipated project schedules, and revised anticipated costs for the two "complete rad removal" alternatives based on the assumption that the deeper intervals in borings WL-210 and WL-235 are not included in the volume of RIM material under the two "complete rad removal" alternatives.

2. SFS Revisions – The existing SFS text, tables and appendices will be amended to include the results of alternative development and evaluation based on exclusion of the deeper intervals in borings WL-210 and 235 in conjunction with the existing discussions that include these depth

intervals as presented in the current SFS report. Subject to EPA comments on the Interim Deliverable, the following specific revisions to the December 2011 SFS report are anticipated:

a. Amend the text of the SFS as follows:
    i. Section 5.3.1 – Include as part of the descriptions of the excavation and disposal alternatives the volumes of RIM and overburden material to be excavated if the reported deeper occurrences in borings WL-210 and WL-235 are not considered in addition to the total volumes already presented in this section
    ii. Sections 6.2.2 and 6.2.3 – Include as part of the descriptions of the excavation and disposal alternatives the volumes of RIM and overburden material to be excavated if the reported deeper occurrences in borings WL-210 and WL-235 are not considered in addition to the total volumes already presented in this section
    iii. Sections 6.2.2.5 and 6.2.3.5 – Add to the discussions of Short-Term Effectiveness, in particular the Protection of the Community, Protection of Workers, and Time Until RAOs are Achieved, discussions relative to the reduced volume of material and consequently reduced time frames that would be associated with excavation and disposal alternatives if the reported deeper occurrences in borings WL-210 and WL-235 are not considered
    iv. Sections 6.2.2.7 and 6.2.3.7 – Add to the discussion of Cost, the estimated costs to implement the excavation and disposal alternatives based on the reduced volume of material and consequently reduced time frames that would be associated with excavation and disposal alternatives if the reported deeper occurrences in borings WL-210 and WL-235 are not considered
    v. Sections 7.2.3 (Short Term Effectiveness) and 7.2.5 (Cost) – Revise the comparative analysis of alternatives to reflect the differences between the short-term risks, schedules and costs that result from inclusion or exclusion of the deeper intervals in borings WL-210 and WL-235

b. Amend the Appendices to the SFS as follows:
    i. Appendix B – Develop and include an alternative excavation plan that does not include excavation of the deeper intervals at WL-210 and WL-235 and calculate the revised volume of RIM and overburden material to be excavated.
    ii. Appendix H – Develop and include estimates of the potential risks to the community and workers based on the volumes of RIM and overburden material to be excavated and revised construction schedules if the deeper intervals in borings WL-210 and WL-235 are not considered
    iii. Appendix I – Prepare additional estimates of Greenhouse Gas Emissions associated with the "complete rad removal" alternatives under a scenario where the deeper intervals in borings WL-210 and WL-235 are not considered

iv. Appendix J – Prepare additional construction schedules for the "complete rad removal" alternatives under a scenario where the deeper intervals in borings WL-210 and WL-235 are not considered
v. Appendix J – Prepare additional estimates of the construction costs (both fiscally constrained and not-fiscally constrained) for the "complete rad removal" alternatives under a scenario where the deeper intervals in borings WL-210 and WL-235 are not considered

Clarifications by EPA

No additional information or clarifications are being requested from EPA at this time relative to this task.

Anticipated Schedule

It is anticipated that it will take approximately two months to develop the interim summary memorandum.

Preparation of a Supplemental SFS report that includes the results of the revised Area 2 excavation volumes and associated evaluations, as described in the interim deliverable summary memorandum, will be performed once EPA comments on the interim deliverable are received and in conjunction with revisions to the existing SFS report required to address the results of the various other additional tasks EPA has requested.

References

Engineering Management Support, Inc. (EMSI), 2011, Supplemental Feasibility Study, Radiologically-Impacted Material Excavation Alternative Analysis, West Lake Landfill Operable Unit-1, December 16.

EMSI, 2000, Remedial Investigation, West Lake Landfill Operable Unit-1, April 10.

May 9, 2013

Mr. Paul Rosasco, P.E.
Engineering Management Support, Inc.
7220 West Jefferson Avenue, Suite 406
Lakewood, CO 80235

RE: Comments on draft Work Plans for Supplemental Feasibility Study (SFS) Amendment, West Lake Landfill Operable Unit 1 (OU-1), Bridgeton, Missouri

Dear Mr. Rosasco:

The Missouri Department of Natural Resources has completed its review of the above referenced documents prepared by Engineering Management Support Inc. (EMSI) and is transmitting the enclosed final comments. This additional work is summarized in a letter from EPA dated October 12, 2012. In that letter, the EPA states that the Respondents agreed to perform the following six additional studies to be documented in an amendment to the SFS report: (1) Alternative Excavation Volume, (2) Partial Excavation Alternative, (3) Apatite Treatment Technologies, (4) recalculation of costs for all alternatives using a seven percent Discount Rate for the Present Value calculations, (5) Alternative Landfill Cap Designs, and (6) Fate and Transport Modeling.

The Department's comments are categorized by either general comments that pertain to all work plans, or by comments that apply to the particular work plan as noted. Please note that these comments pertain to the original drafts of the work plans you provided on specified dates, and that any modification(s) to the work plans, due to clarification from EPA or otherwise, may require additional review by the Department.

We are available to discuss these comments with you and the EPA for clarification, and can also review any interim deliverables pertaining to these work plans.

Thank you for giving us the opportunity to review and comment on these documents. If you have any questions pertaining to these comments, please contact me by phone at (573)751-3107; by written correspondence to my attention at the Missouri Department of Natural Resources, P.O. Box 176, Jefferson City, MO 65102; or e-mail to shawn.muenks@dnr.mo.gov.

Sincerely,

HAZARDOUS WASTE PROGRAM

Shawn Muenks

Shawn Muenks, P.E.
Federal Facilities Section

SM:ls

Enclosure

c: Mr. Dan Gravatt, U.S. Environmental Protection Agency

MISSOURI DEPARTMENT OF NATURAL RESOURCES

Comments on the
West Lake Landfill Operable Unit 1
SFS Amendment Work Plans

GENERAL COMMENTS PERTAINING TO ALL WORK PLANS:

1.) ARARs and RAOs
The work plans do not describe how potentially Applicable or Relevant and Appropriate Requirements (ARARs) or Remedial Action Objectives (RAOs) will be identified. Will the ARARs and RAOs as specified in the SFS pertain to these new studies as well? If no new ARARs or RAOs are needed, how will this be confirmed? Please include a discussion in the work plans on how these components will be selected and/or updated from those in the SFS.

2.) NCP Evaluations
It is noted that these additional studies may result in new remedial alternative(s) or modifications to the ROD-selected remedy (i.e. the partial excavation alternative, alternative landfill cap designs, and treatment technologies). Please include a discussion in the appropriate work plan(s) on how the new or modified alternative(s) will be evaluated using the threshold and primary balancing criteria set forth in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR § 300.430 (EPA, 2009a). The relative performance of each new or modified alternative should be evaluated using the NCP criteria and compared to the original ROD-selected remedy and the SFS "complete rad removal" alternatives.

3.) Work Plan Titles
It is noted that some work plans are titled as such while others are titled "Scope of Work and Schedule". If there is a specific reason for this, please elaborate in the appropriate work plans.

WORK PLAN SPECIFIC COMMENTS:

I. Work Plan – Alternative Area 2 Excavation Depths and Volumes (dated 11/12/2012)

4.) Page 1: The second, third and fourth paragraphs of the Introduction focus on verification of deep radiologically-impacted material (RIM) in borings WL-210 and WL-235 using the same data that the EPA National Remedy Review Board deemed unreliable. The Department feels that such an argument is irrelevant to the objective of this work plan and requests that these paragraphs be removed. As stated in previous comments, the Department believes minimal sampling could confirm/disprove presence of such deep RIM (see Department Comments on draft Supplemental Feasibility Study, General Comment #1, dated November 19, 2010).

5.) Page 3: In addition to those sections of the SFS identified for revision during this study, the Department has identified the following sections which discuss deep RIM in Area 2 for consideration during SFS revisions:
   2.2.4 Estimated Volume of RIM

6.2.2.6 Implementability
6.2.2.6.1 Ability to Construct and Operate the Technology
6.2.3.6 Implementability
6.2.3.6.1 Ability to Construct and Operate the Technology
7.2.4 Implementability
Figure 27 - Evaluation of Remediation Technologies and Process Options
Table 10 - Comparative Analysis of Alternatives

Please review these sections for potential revisions to the SFS as they pertain to exclusion of the deep RIM from borings WL-210 and WL-235.

II. Work Plan – Partial Excavation Alternative (dated 12/4/2012)

6.) The Department has reviewed the referenced criteria from the Operable Unit 1 Feasibility Study (FS) used to define the FS Partial Excavation Alternative. It is not clear from the FS how the criteria of 1,000 pCi/g for radionuclide activity and 500,000 counts per minute (cpm) were derived to define a partial excavation alternative. Specifically, the FS states on page 83, second last paragraph, "The evaluations presented in Section 4.4.3 and Appendix B support the conclusion that there are no discrete, accessible principal threat wastes meeting the hot spot criteria as described in EPA's presumptive remedy guidance." The FS then goes on to calculate volumes of waste to be excavated using 100 pCi/g and 100,000 cpm, the values are then increased to 1000 pCi/g and 500,000 cpm to determine what appears to be an arbitrary volume of RIM for "hot spot" removal.

Section 2.2.8, page 22, of the SFS states, "Because the purpose of the SFS is to provide a thorough evaluation of the potential 'complete rad removal' alternatives relative to the ROD-selected remedy, it is conservatively assumed that principal threat wastes may be present within OU-1." The Department is familiar with the process at other sites to use removal/containerization as the treatment option for principal threat wastes to reduce the toxicity and mobility. Therefore, the criteria used to define "principal threat waste" is also used to define the level of contaminants that will be removed under a partial excavation alternative. Will principal threat waste be used to determine the partial excavation alternative criteria presented in this work plan? Please include an explanation of the scientific approach used to define the criteria for the partial excavation alternative.

III. Scope of Work and Schedule – Evaluation of the Use of Apatite/Phosphate Treatment Technologies

7.) As mentioned in the previous comment to the partial excavation alternative, the SFS states that it is assumed that principal threat wastes may be present within OU-1. Will this treatment technology evaluation be used to determine potential treatment for principal threat waste? If so, please include this discussion in the work plan.

8.) Page 1: The second sentence under "Approach" states, "The RAOs developed for OU-1 did not include direct treatment of the waste materials or treatment of groundwater." As stated in comment #1, please describe any new RAOs that may be needed in the SFS Amendment to address this evaluation.

9.) Page 2: The second item under "Results of Preliminary Evaluations" states, "Bench-scale testing at Oak Ridge has indicated that apatite may be effective in treating uranium and heavy metals in groundwater (this reportedly was to be followed up by a pilot-scale test but reports of the results of the pilot-scale testing, if performed, have not yet been located)". Is a pilot-scale test at West Lake Landfill being considered to evaluate the apatite treatment technology? If so, please include a discussion on the feasibility of this pilot-scale test in the work plan.

10.) Page 2: The fourth item under "Results of Preliminary Evaluations" states, "DOE representatives indicated that owing to the potential disruption in chemical equilibrium within the waste matrix, such an application could result in an increase in leaching potential of radionuclides instead of a reduction in leaching potential that would be intended by such an application." Please include a citation for this statement.

11.) Page 3: Numbered list that begins with "Furthermore, EPA previously determined that there is no unacceptable risk of groundwater contamination at the site. Specifically, the ROD contains the following conclusions:". The Department is unclear on the intended purpose of this list. Is this list given to support the fact that groundwater treatment was not included in the SFS or is it an argument against the need to evaluate groundwater treatment technologies at this time? Please note that the ROD goes on to state on page 22, last sentence of the section from which these quotes were taken, "However, radionuclide and nonradionuclide contamination is present in the landfill units; the potential for leaching to groundwater and off-site migration is a pathway that should be addressed as part of the remedy for the Site." Furthermore, current groundwater data is currently being collected and should be analyzed and included in the evaluation of potential groundwater treatment technologies. Please consider removing this list from the work plan or clarifying its purpose.

12.) Page 3: Third paragraph, first sentence states, "Consequently, groundwater was not determined to be a media of concern (i.e., no plume of groundwater contamination exists) and treatment of groundwater was not identified as a potential response action for the site in the prior FS or SFS." The work plan should also mention that current groundwater data is being collected to verify the ROD determinations.

13.) Page 5: Opening sentence of numbered list states, "EMSI wastes to discuss with EPA the possible role of apatite or other groundwater treatment technologies relative to preparation of a Supplemental SFS report. These include the following:". Should the word *wastes* be replaced with *wants*?

14.) Page 5: Numbered list, item #1. This item asks, "How the SFS should address the lack of/minimal nature of impacts to groundwater relative to any evaluation of potential apatite treatment technology for groundwater given that: a. Groundwater was not identified as a media of concern in the FS or SFS and therefore general response actions and remedial technologies for groundwater were not identified or evaluated in either document. [and] b. Groundwater treatment was not identified as being necessary (see above language from the ROD)." Please refer to comment #11 in which the Department questions the purpose of quoting the ROD language. The Department reiterates its position that the determinations of groundwater impacts that led up to the ROD should not be the sole argument to abandon the evaluation of groundwater treatment technologies until the current groundwater sampling data has been analyzed.

IV. Work Plan – Additional Present Value Cost Estimates (dated 11/12/2012)

15.) Page 1: The first sentence of the second paragraph under "Approach" states, "A narrative will also be prepared to explain why both rates are being used for the SFS." Please include such narrative in the work plan instead of the SFS Amendment. The work plan should contain information on why this is being done.

V. Scope of Work and Schedule – Alternative Cover Designs (dated 2/3/2013)

16.) Page 2: The first sentence of the third paragraph under the section titled "Evapotranspiration Cover" states, "Review of sites contained in EPA's alternative cover database http://cluin.org/products/altcovers/ indicates that only two alternative cover designs have been documented in Missouri; one is a demonstration project installed in 1995 for an inactive fly ash waste pond at a power plant and the other is an ET cover constructed in 2003 over contaminated soil at a former wood treating plant." What about sites in other states? The Department notes that there are over 200 sites nationwide (according to the cluin website) where ET cover is being designed or used, many of which are located in the Great Plains. Please consider including these sites in your review.

17.) Page 3: The first sentence under the section titled "Evapotranspiration Cover Design" states, "The initial screening of the potential implementability of an ET cover will evaluate the thickness of the soil cover that would be required to prevent percolation of precipitation from reaching the underlying waste materials." The Department emphasizes the need for these landfill cover alternatives to meet Solid Waste Regulations ARARs. Please include discussion in the work plan how these ARARs will be evaluated (see comment #1).

18.) Page 3: The last sentence of the first paragraph under the section titled "Evapotranspiration Cover Design" states, "Modeling of the anticipated cover thickness would be performed using the UNSAT-H model (Fayer, 2000) or HYDRUS-1D (Šimůnek,et al., 2005)." The Department is not familiar with these modeling tools. Please provide references to where we can find more information about these modeling tools such as websites or studies where these tools have been used at other sites.

19.) Page 3: The first sentence of the second paragraph under the section titled "Evapotranspiration Cover Design" states, "If the technical implementability screening indicates that infiltration of precipitation can be minimized with an ET cover employing a fine-grained layer 5-feet thick or less, then this technology would be considered potentially implementable and would be subjected to further evaluation of its potential effectiveness, implementability and cost." Why is the fine-grained layer restricted to 5-feet thick or less?

20.) Page 5: The first sentence of the last paragraph under the section titled "Deliverables" states, "In the event that ET cover technology and/or GCL-alternate cover technology are found to be potentially applicable based on the site and waste conditions, there may be a need to develop one or more additional remedial alternatives for detailed analysis in the Supplemental SFS report." The Department is confused by this statement. Isn't the purpose of this work plan to develop additional *potential* remedial alternative(s) that utilize alternative cover designs for detailed analysis in the Supplemental SFS report?

VI. Scope of Work and Schedule – Fate and Transport Modeling (dated 4/19/2013)

21.) Page 1: The last paragraph under the Introduction states, "It is assumed that modeling calculations will be performed on the basis of existing site-specific data, augmented where necessary with information and values obtained from technical literature and/or derived from professional experience." Does this include groundwater data that was collected in July-August 2012 as well as groundwater data currently being collected? If groundwater data is being used in the modeling calculations, the recent data should be included in order to best represent site conditions.

22.) Page 2: The first sentence of the last paragraph under the section titled "Background" states, "As defined in the OU-1 ROD, the new landfill cover for Areas 1 and 2 would consist of the following, from bottom to top: 2-ft of rock consisting of well-graded pit run rock and/or concrete/asphaltic rubble ranging from sand-sized up to 8-inches; 2-ft of compacted clay or silt that when compacted at optimum moisture content possesses a coefficient of permeability of 1 x 10-5 cm/sec or less; and 1-ft of soil suitable of supporting vegetative growth." It is noted that the OU-1 ROD does not specify the bottom layer of the landfill cover to consist of "2-ft of rock consisting of well-graded pit run rock and/or concrete/asphaltic rubble ranging from sand-sized up to 8-inches". The OU-1 ROD refers to this layer as a "rubble or rock armoring layer". Please use the OU-1 ROD verbiage. The Department has previously commented on the need to further study the design of the armoring layer to meet the longevity requirements as specified in the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) guidance for a 1000-year design period. Also, does "a coefficient of permeability of 1 x 10-5 cm/sec or less" agree with the UMTRCA guidance?

23.) Page 3: The first sentence of the section titled "Fate and Transport Conceptual Site Model" states, "Because the overall mass of radium at the Site is small and future infiltration through the landfill materials will be less than at present due to the planned emplacement of an additional landfill cover over the existing landfill cover material, it might be expected that concentrations of radium will necessarily decline in the future." The Department does not understand the purpose of this statement. Please explain the relevancy of this statement as it pertains to ingrowth of radium over time. The fact that ingrowth of radium will result in increased concentrations of radium over time should be considered in development of the conceptual site model.

24.) Page 4: The third sentence of the first paragraph under the section titled "Primary Site-Specific Features" states, "This radiologically-impacted material (RIM) is currently covered by old landfill cover material." The previous overland gamma surveys conducted and analytical data collected during the OU-1 Remedial Investigation identified areas where RIM is at the surface. Please revise this statement to include presence of surface RIM.

25.) Page 5: Table 1, Primary Events and Processes of Potential Radionuclide Fate and Transport at the Site. Please consider adding a Features, Events, and Processes (FEP) Element under "Events" which describes the inward gradient that may exist in relation to the active leachate collection at the Bridgeton Sanitary Landfill and the changes to the groundwater transportation model in the event the leachate collection would cease. The Department believes this is an important parameter to include in the fate and transport modeling as it plays an important role in potential for off-site migration.

26.) Page 8: The third sentence of the third paragraph under the section titled "Graded Approach" states, "If regulatory standards are not exceeded then no further analyses will be required." Please identify what regulatory standards are being used in this determination.

27.) Page 8: The third sentence under the section titled "Simulation Code Selection" states, "Since parameterization of the geochemical component of the model is likely subject to more variability and uncertainty than the groundwater flow component of the model - given the large number of chemical processes that potentially affect radium fate and transport – advective-dispersive migration will be simulated as one-dimensional (1-D), coupled with a rigorous treatment of the complex geochemical processes." Please explain how the "groundwater flow component of the model" will be represented. Will this be done with potentiometric surface maps? If so, please include recent data in this component of the model.

28.) Page 11: The first sentence under the section titled "Model Validation and Predictive Sensitivity Analysis" states, "Historical groundwater data have exhibited few detections of radionuclides." Please consider including groundwater data which was collected in July-August 2012 and data which is currently being collected to support this statement.